220th AAS Meeting – Anchorage, AK June, 2012

AAS Summer Meeting Abstracts

100 – Welcoming Address by UAA Chancellor Tom Case
AAS Welcomes New Division

Invited Session – Ballroom B, Dena'ina Center – 6/11/2012 8:00:00 AM to 6/11/2012 8:30:00 AM

During the welcome remarks just prior to the Kavli Lecture, the AAS will welcome its newest specialist division,Laboratory Astrophysics Division, as a formal part of the Society. President DebraElmegreen will present a certificate commemorating this historic occasion to membersof the Working Group who helped motivate the formation of the division.

101 – Kavli Prize: Laboratory Astrophysics as Key to Understanding the Universe

Invited Session – Ballroom B, Dena'ina Center – 6/11/2012 8:30:00 AM to 6/11/2012 9:20:00 AM

101.01 – **Laboratory Astrophysics as Key to Understanding the Universe**

Ewine F. van Dishoeck[1]

[1]*Sterrewacht Leiden, Netherlands.*

8:30 AM - 9:20 AM

Modern astrophysics is blessed with an increasing amount of high quality observational data on astronomical sources, ranging from our own solar system to the edge of the Universe and from the lowest temperature clouds to the highest energy cosmic rays. Spectra containing thousands of features of atoms, molecules, ice and dust are routinely obtained for stars, planets, comets, the ISM andstar-forming regions, and in the near future even for the most distant galaxies. Realistic models of exo-planetary atmospheres require information on billions of lines. Theories of jets from young stars benefit from plasma experiments to benchmark them. Stellar evolution theories and cosmology rely heavily on accurate rates for nuclear fusion reactions. The first stars could not have formed without the simplest chemical reactions taking place in primordial clouds. Particle physics is at the heart of finding candidates for the mysterious dark matter. There is no doubt that laboratory astrophysics, which includes theoretical calculations, remains at the foundation of the interpretation of observations and truly 'makes astronomy tick'.

In this talk, several recent developments in determining these fundamental data will be presented which have resulted in significant advances in our understanding of astrophysical environments. Often, a comparatively minor investment in basic studies can greatly enhance the scientific return from missions. Examples will be taken from each of the 6 themes of the new Laboratory Astrophysics dvision of the AAS (www.aas.org/labastro/lawg_charter.php): atomic, molecular, solid matter, plasma, nuclear, and particle physics. Special attention will be given to recent results from infrared and millimeter facilities, including Herschel and ALMA, which reveal rich spectra of water and organic molecules in star- and planet forming zones. Their interpretation is greatly added by the application of ultra-high vacuum surface science techniques to astrophysical problems.

102 – Multiple Populations in Globular Clusters: Basic Data & Consequences

Meeting-in-a-Meeting – Ballroom C, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

This session focuses on an overview of multiple populations in globular clusters, including basic data and implications for the formation and evolution of the Galaxy.

102.01 – **Multiple Populations in Galactic Globular Clusters: Overview and Context**

Ata Sarajedini[1]

[1]*Univ. of Florida.*

10:00 AM - 10:22 AM

I will begin by providing a historical overview of multiple populations as they occur in globular clusters. From our earliest recognition that the Galactic globular Omega Centauri exhibits a complex stellar population to today's realization regarding the nature of multiple populations, we have come to expect the unexpected in this regard. I will then discuss the concept of multiple populations from both a photometric and spectroscopic point of view since, in many ways, the two perspectives are unique and provide different insights into the phenomenon. The talk will conclude with an overview of the implications multiple populations have for our understanding of star cluster and galaxy formation and evolution.

102.02 – **What Is A Globular Cluster? Discovery Of An Old, Massive, Star Cluster With A Single Stellar Population**

Douglas Geisler[1], S. Villanova[1]

[1]*Universidad de Concepcion, Chile.*

10:22 AM - 10:44 AM

Globular Clusters (GCs), long considered as ideal Single Stellar Populations, are now known to harbor a wide variety of chemical inhomogeneities. In particular, Carretta et al. (2009) showed that all GCs studied to date have at least a spread (or anticorrelation) in the light-elements O and Na. Indeed, they suggest a new definition of a GC as a cluster which exhibits such an anticorrelation, with the implication that all GCs, at least those above a certain mass limit, must posses this characteristic. The explanation is that GCs had at least two epochs of star formation and thus two generations of stars, where the second was formed from gas polluted by processed material produced by massive stars of the first. This multiplicity can only happen if the initial cluster mass exceeds a threshold above which stellar ejecta are retained and eventually a second generation is formed. A determination of this mass-threshold is mandatory in order to understand how GCs form. However, no convincing case of a single population GC has so far been found. We present a detailed abundance analysis of a large sample of stars from the ''GC" Ruprecht 106 observed with UVES@VLT2. We show that Ruprecht 106 is the first convincing example of a true single population ''GC". It is old (12 Gyrs) and, at odds with other GCs, has no alpha-element enhancement and a much lower C+N+O content. The abundance pattern points toward an extragalactic origin. Its present day mass can be assumed as a lower limit for the initial mass threshold below which no second generation is formed.

102.03 – **Multiple Populations in (Massive) Clusters**

Angela Bragaglia[1]

[1]*INAF-Osservatorio Astronomico di Bologna, Italy.*

10:44 AM - 11:06 AM

In recent years photometric and spectroscopic evidence showed that globular clusters host (at least) two stellar generations, with slightly different ages, but wildly different chemical abundances of light elements. This phenomenon appears to be tied to the cluster mass and its formation mechanism. Stars in the younger, less massive open cluster, on the other hand, seem to enjoy a very homogeneous chemical composition. However, there are very few open clusters where more than a handful of stars have been chemically characterized.

To better understand the formation mechanism of clusters it is important to determine the mass limit and the conditions under which clusters can retain matter from a first generation and form a new one. I will focus on the observations required to characterize the grey zone between open and globular clusters, where they overlap in age and mass, presenting both spectroscopic (e.g. measure of Na and O) and photometric (e.g. use of Stromgren filters) tests.

102.04 – **A Bayesian Technique to Recover Multiple Stellar Populations**

Ted von Hippel[1]

[1]*Embry-Riddle Aeronautical University.*

11:06 AM - 11:28 AM

The recent realization that many globular clusters host multiple populations has not only challenged our conception of what globular clusters actually are, but has also thoroughly challenged the statistical techniques we use to analyze these systems. This modern discovery is driven by superb data from the Hubble Space Telescope and its newest instruments. Interpreting these data requires precisely applying modern stellar evolution and atmosphere models. Yet, while the quality of the data is orders of magnitude better than the single-channel photometer and photographic plate data of the 1960's and the current stellar evolution models vastly surpass the models and hardware of that epoch, research groups are still hampered by data fitting techniques that have hardly progressed over the last half century. I will describe a new Bayesian software suite for deriving parameters for single stellar populations and our first forays into multiple stellar populations. Our Bayesian technique yields better precision in the ages, distances, etc. for stars and clusters, provides a fuller understanding of errors and correlations among the derived parameters, and allows us to attack a range of problems in stellar evolution in a statistically consistent manner for the first time. We gratefully acknowledge support from NASA under grant 10-ADAP10-0076.

103 – Extragalactic Gamma-ray Background (EGB): The Isotropic Gamma-Ray Background Measurement and the Contribution From Jet-Dominated Sources

Meeting-in-a-Meeting – Summit Hall 4, Egan Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

The origin of the Isotropic Gamma-ray Background (IGRB) is one of the fundamental unsolvedproblems in astrophysics. The intensity of this isotropic radiation has been measured with precision by Fermi and found to be compatible with a featureless power law up to 100 GeV.Its nature is however still enigmatic. Blazars, active galactic nuclei with a relativistic jetclosely aligned to the line of sight, are the most numerous population detected at gamma-rays and represented for a long time the primary candidate to explain the IGRB emission. However, there are evidencethat they do contribute ≤30% of the IGRB. Leaving the remaining ~70% unexplained.The first session of this meeting will focus on the most recent measurement of the IGRB with Fermiand on the refined estimates of the contribution of blazars and jet-dominated sources in general.

103.01 – **Fermi LAT Results on the Intensity and Origin of the Diffuse Extragalactic Gamma-ray Background**

Markus Ackermann[1]

[1]*DESY, Germany.*

10:00 AM - 10:15 AM

The data collected by the Fermi Large Area Telescope (LAT) for almost four years enable a huge step forward in measuring and understanding the origins of the extragalactic diffuse gamma-ray background (EGB). The EGB originates from the superposition of different populations of unresolved sources with possible contributions from genuinely diffuse and exotic processes. In most parts of the sky it is sub-dominant to the Galactic diffuse emission, which represents a foreground to be subtracted to allow a measurement of the EGB intensity.

Due to the long exposure, an improved event selection, better understanding of the Galactic diffuse foregrounds and the charged particle backgrounds, we can now extend the measurement of the spectrum of the EGB to the energy range between 100 MeV and several hundred GeV. Furthermore, population studies based on resolved LAT sources allow to constrain the contribution of individual classes of unresolved sources to the EGB.

103.02 – **Ultra-high Energy Source Contributions to the Extragalactic Gamma-Ray Background**

Charles D. Dermer[1]

[1]*NRL.*

10:15 AM - 10:30 AM

The ingredients of the extragalactic gamma-ray background (EGB) at GeV-TeV energies must contain contributions from all source classes that are known to emit at these energies, including blazars, radio galaxies, star-forming galaxies, pulsars, and gamma-ray bursts. An uncertain contribution should be provided by cosmic-rays accelerated in cluster formation shocks, as well as from exotic processes, including dark matter annihilation and decay. After presenting an overview, the focus of this talk will be on contributions to the EGB from blazars emitting at >>TeV energies as well as from ultra-high energy cosmic rays. These ultra-high energy sources induce secondary radiations that cascade into the TeV and GeV band. Measurements of the EGB at very high gamma-ray energies can be used to constrain the number and distribution of such sources.

103.03 – **The Contribution of Millisecond Pulsars to the Isotropic Gamma-Ray Background**

Francesco Massaro[1], M. Ajello[1]

[1]*Stanford University.*

10:30 AM - 10:45 AM

The contribution of millisecond pulsars (MSPs) to the Isotropic Gamma-Ray Background (IGRB) could be extremely relevant since they are the second largest population detected at high Galactic latitudes. However, previously theoretical estimates did not carefully take into account Fermi source detectability, and relied on simple models of the MSP sky distribution. I will present the estimate the integrated diffuse emission from MSPs by the integration of their flux distribution, taking into account their Fermi LAT detectability combined with the synthetic evolutionary models of the MSP population. This investigation also provides an estimate of the number of yet unresolved MSPs, useful to constrain their contribution to the Galactic stellar population, and to address the number of future MSPs that could be discovered by Fermi.

103.04 – **Constraints on Blazar Population Models from the Anisotropy of the Diffuse Gamma-Ray Background**

Jennifer M. Siegal-Gaskins[1], A. Cuoco[2], E. Komatsu[3]

[1]*California Institute of Technology,* [2]*The Oskar Klein Centre for Cosmo Particle Physics, Sweden,* [3]*The University of Texas at Austin.*

10:45 AM - 11:00 AM

Recently the Fermi LAT has reported the first measurement of small angular-scale anisotropies in the diffuse gamma-ray background. The contribution of unresolved sources to the background is expected to induce characteristic anisotropies, and so the measured angular power represents a new observable that can be used to constrain the properties of known and proposed gamma-ray source populations. I will present strong new constraints on blazar population models from the measured anisotropy of the gamma-ray background, and discuss the implications of these results for other gamma-ray source classes that may contribute to this emission.

103.05 – **The Contribution of Radio Galaxies to the Extragalactic Gamma-ray Background**

Yoshiyuki Inoue[1]

[1]*Kyoto University, Japan.*

11:00 AM - 11:15 AM

The origin of the extragalactic gamma-ray background (EGRB) radiation has been a mystery in astrophysics for a long time. Recently the Fermi gamma-ray satellite (Fermi) has revealed that ~22% of the unresolved EGRB would be explained by blazars, which are one population of active galactic nuclei (AGNs). The remaining ~78% of the unresolved EGRB is still unknown. We estimate the contribution of gamma-ray loud radio galaxies, which are misaligned AGNs recently detected by Fermi, to EGRB using the radio luminosity function of radio-loud AGNs with the correlation between the radio and gamma-ray luminosities. We find that ~25% of the unresolved EGRB will be explained by gamma-ray loud radio galaxy population. We also discuss further about the origin of EGRB by comparing the Fermi EGRB data with our studies on various AGN populations' contribution to EGRB.

103.06 – **Contribution of BL Lacertae Objects to the Extragalactic Gamma-ray Background**

Marco Ajello[1], M. Shaw[2], R. W. Romani[2], C. Dermer[3], F. Massaro[1], Fermi LAT collaboration

[1]*SLAC/KIPAC,* [2]*Stanford University,* [3]*US Naval Research Laboratory.*

11:15 AM - 11:30 AM

BL Lacertae (BL Lac) objects represent one of the most interesting source populations in the gamma-ray sky. Contrary to flat-spectrum radio quasars and even misaligned radio galaxies, the number of BL Lac objects detected by Fermi in its "clean" samples is dramatically increasing, going from 275 objects detected in the first year to 395 in the second year. They include sources detected with a hard spectrum up to a redshift of ~1. This population can thus provide a substantial contribution to the intensity of the Extragalactic Gamma-ray Background (EGB) at the highest (i.e., >10 GeV) energies. In this talk, I review the properties of BL Lac objects at gamma-ray energies and current efforts to constrain their redshifts. I will also present the first luminosity function of gamma-ray selected BL Lac objects and an estimate of the contribution of this population to the EGB. Implications for the formation of the >10 GeV background will also be discussed.

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104 – New Horizons for Science From the Moon: Cosmic Dawn, Reionization, & Low Frequency Astrophysics

Meeting-in-a-Meeting – Ballroom A, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

This session will discuss advances in theory, observations, and instrumentation for low frequency astrophysics and cosmology from the ground and from the Moon. As one example, the Astro2020 Decadal Report, "New Worlds, New Horizons in Astronomy & Astrophysics" singles out Cosmic Dawn as a top science objective for this decade. When and how did the first galaxies form out of cold clumps of hydrogen gas? What signatures did the first stars leave on their surroundings? When and how did reionization occur? The highly redshifted (z≈6-35) 21-cm hyperfine transition from neutral hydrogen at 40-200 MHz is a powerful probe of this epoch. Concepts for low frequency telescopes,including dipoles in lunar orbit and arrays on the radio-quiet lunar farside, will be presented in this session that will constrain Cosmic Dawn as COBE and WMAP did for the CMB.

104.01 – **Dark Ages and Cosmic Dawn: Theoretical Expectations**

S. Peng Oh[1]

[1]*UC, Santa Barbara.*

10:00 AM - 10:15 AM

I review theoretical expectations for the treasure trove of cosmological and astrophysical information in the low frequency sky.

104.02 – **Recent Results from the Precision Array for Probing the Epoch of Reionization [PAPER]**

Jonathan Pober[1]

[1]*UC Berkeley.*

10:15 AM - 10:30 AM

The Precision Array for Probing the Epoch of Reionization (PAPER) is an experiment to detect the heating and reionization of the IGM through the highly redshifted 21-cm line of neutral hydrogen. This talk will describe our current deployments in Green Bank, West Virginia and the South African Karoo. I will present recent simulations and new observational data which illustrate our "delay spectrum" approach to foreground isolation and power spectrum detection. To conclude, I will present a proposed Baryon Acoustic Oscillation Broadband and Broad-beam (BAOBAB) array, which will use the delay spectrum technique at frequencies of 600-900 MHz to detect the power spectrum of neutral hydrogen in the post-reionization epoch.

104.03 – **HI at z ~ 20: The Large Aperture Experiment to Detect the Dark Ages**

Lincoln J. Greenhill[1], D. Werthimer[2], G. Taylor[3], S. Ellingson[4], LEDA Collaboration

[1]*Harvard-Smithsonian, CfA,* [2]*University of California, Berkeley,* [3]*University of New Mexico,* [4]*Virginia Tech.*

10:30 AM - 10:45 AM

When did the first stars form? Did supermassive black holes form at the same time, earlier, or later? One of the great challenges of cosmology today is the study of these first generation objects. The Large Aperture Experiment to Detect the Dark Ages (LEDA) project seeks to detect, in total-power, emission from neutral Hydrogen (21 cm rest wavelength) in the intergalactic medium about 100 million

years after the Big Bang (redshifts ~ 20). Detection would deliver the first observational constraints on models of structure formation and the first pockets of star and black holes formation in the Universe.

LEDA will develop and integrate by 2013 signal processing instrumentation into the new first station of the Long Wavelength Array (LWA). This comprises a large-N correlator serving all 512 dipole antennas of the LWA1, leveraging a packetized CASPER architecture and combining FPGAs and GPUs for the F and X stages. Iterative calibration and imaging will rely on warped snapshot imaging and be drawn from a GPU-enabled library (cuWARP) that is designed specifically to support wide-field full polarization imaging with fixed dipole arrays. Calibration techniques will include peeling, correction for ionospheric refraction, direction dependent dipole gains, deconvolution via forward modeling, and exploration of pulsar data analysis to improve performance. Accurate calibration and imaging will be crucial requirements for LEDA, necessary to subtract the bright foreground sky and detect the faint neutral Hydrogen signal. From the computational standpoint, LEDA is a O(100) TeraFlop per second challenge that enables a scalable architecture looking toward development of radio arrays requiring power efficient 10 PetaFlop per second performance. Stage two of the Hydrogen Epoch of Reionization Array (HERA2) is one example.

104.04 – **From Ground to Space: A Roadmap with Robotic & Exploration Elements**

T. Joseph W. Lazio[1], J. Bowman[2], J. Burns[3], W. Farrell[4], D. Jones[1], J. Kasper[5], K. Stewart[6], K. Weiler[7]

[1]*JPL,* [2]*ASU,* [3]*U. Colorado, Boulder,* [4]*NASA/GSFC,* [5]*CfA,* [6]*NRL,* [7]*CPI.*

10:45 AM - 11:00 AM

Ground-based 21 cm cosmology and astrophysics measurements are underway, with initial limits on the H I signal at various redshifts established. The Moon is a unique platform for 21 cm cosmology and astrophysics because its farside is shielded from intense terrestrial emissions and its ionosphere is significantly less dense than Earth's.

There is international interest in returning humans to the Moon, with instrument packages and telescopes deployed as part of Exploration activities. A roadmap for the staged deployment of lunar telescopes is

Stage I: On-going ground-based activities to develop the instruments and techniques, as well as detect or place austere limits on the redshifted H I 21 cm line.

Stage IIa: One antenna (or a few) on a lunar orbiter. The prime science is to detect the sky-averaged, redshifted H I 21 cm line that is excited by the UV and X-ray fields of the first stars and accreting black holes.

Stage IIb: One antenna (or a few) on the lunar surface. A near-side antenna would monitor the lunar ionosphere and track the balance between solar wind-induced effects and lunar interior outgassing; a far-side antenna would study the redshifted 21 cm line. Deployment could be done either during astronaut sorties or telerobotically. This stage could occur in parallel with Stage IIa.

Stage III: A near-side telescope capable of studying particle acceleration within the inner heliosphere (~100 antennas distributed over 1 km). Such a telescope could detect the magnetically-generated emissions from solar system planets, and potentially from extrasolar planets.

Stage IV: A far-side telescope capable of imaging the H I 21 cm line from Cosmic Dawn and into the Dark Ages (~ 10^5 antennas over 10 km). It would also be capable of detecting the magnetospheric emission from extrasolar planets.

104.05 – **The Dark Ages Radio Explorer: Constraining Cosmic Dawn from the Global 21-cm Signal**

Jack O. Burns[1]

[1]*Univ. of Colorado at Boulder.*

11:00 AM - 11:15 AM

In New Worlds, New Horizons, Cosmic Dawn was singled out as one of the top astrophysics priorities for this decade. Specifically, the Astro2010 report asked “when and how did the first galaxies form out of cold clumps of hydrogen gas and start to shine -when was our cosmic dawn?” It proposed “astronomers must now search the sky for these infant galaxies and find out how they behaved and interacted with their surroundings.” This is the science objective of DARE - to search for the first stars, galaxies, and black holes via their impact on the intergalactic medium (IGM) as measured by the highly redshifted 21-cm hyperfine transition of neutral hydrogen. DARE will probe redshifts of 11-35 (Dark Ages to Cosmic Dawn) with observed HI frequencies of 40-120 MHz. DARE will observe expected spectral features in the global signal of HI that correspond to stellar ignition (Lyman-alpha from the first stars coupling with the HI hyperfine transition), X-ray heating/ionization of the IGM from the first accreting black holes, and the beginning of reionization (signal dominated by IGM ionization fraction). We propose to observe these spectral features with a broad-beam bi-conical dipole antenna along with a receiver and digital spectrometer that has high heritage from the ground-based EDGES experiment. We will place DARE in lunar orbit and take data only above the farside, a location known to be free of human-generated RFI and with a negligible ionosphere. In this talk, we will present the mission concept including initial results from an engineering prototype in western Australian which is designed to perform end-to-end validation of the instrument and our calibration techniques. We will also describe our signal extraction tool, using a Markov Chain Monte Carlo technique, which measures the parameterized spectral features in the presence of substantial Galactic and solar system foregrounds.

104.06 – **Steep Spectrum Radio Sources in Galaxy Clusters**

Tracy E. Clarke[1]

[1]*Naval Research Lab..*

11:15 AM - 11:30 AM

Steep spectrum radio emission associated with galaxy clusters comes from compact central active galactic nuclei (AGN) driven radio sources in dense cool core clusters as well as from large regions of diffuse (halo and relic) emission associated with dynamically complex merging systems. These radio halos and relics are best traced at low radio frequencies where details of their morphology, location and spectral index distribution can be used to probe the underlying acceleration mechanism(s) as well as important details of large scale structure formation. Low frequency radio observations also play an important role in the study of AGN feedback into the intracluster medium and the regulation of cooling cores. While spectacular results are coming from the current generation of low frequency instruments, there will soon be a new revolution in studies of steep spectrum sources with the upcoming generation of low frequency interferometers on Earth and ultimately the moon.

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105 – The Deepest View of the X-ray Universe: 4 Ms Chandra Deep Field Results I

Meeting-in-a-Meeting – Summit Hall 3, Egan Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

This session will cover recent results from the deepest X-ray survey of the Universe, theChandra Deep Field 4 Ms survey. The two 90-minute sessions begin with an overview ofX-ray surveys that have already taken place as well as a view of the future with newmissions such as NuSTAR and eROSITA. Speakers from a variety of topics ranging fromGalactic stars, high-redshift galaxies and galaxy groups will report on what this ultradeepview in the X-rays reveals. We envision a 30 minute overview talk on X-ray surveys,followed by a 15-minute description of the sources of the CDF-S (number counts andsource types). The second session will begin with a talk on normal galaxies whichare among the very faintest X-ray sources in the 4 Ms CDF-S.

105.01 – **An Overview of Deep X-ray Surveys: "Time Machines" for Investigating Supermassive Black Hole Accretion and Endpoints of Stellar Evolution**

W. Niel Brandt[1]

[1]*Penn State Univ..*

10:00 AM - 10:24 AM

Cosmological X-ray surveys over the past 13 years have dramatically improved understanding of the majority populations of active galactic nuclei (AGNs) over most of the history of the Universe. At the same time, they have also opened a window into the X-ray binary populations of distant starburst and normal galaxies. I will present a review of the deep X-ray surveys executed to date by Chandra and XMM-Newton, with an emphasis on the Chandra Deep Fields, along with a description of the essential multiwavelength data that complement these surveys. I will also briefly present some science highlights coming from these surveys including results on AGN demography, physics, and ecology and galaxy X-ray evolution. I will end by describing some key unresolved questions and future prospects.

105.02 – **The 4 Ms CDF-S Number Counts: Pervasive Active Galactic Nuclei and the Ascent of Normal Galaxies**

Bret Lehmer[1]

[1]*Johns Hopkins University.*

10:24 AM - 10:46 AM

In this talk, I will present the latest estimates of the extragalactic X-ray source number counts, based on the 4 Ms CDF-S, 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 ~45% of the total number counts above the 0.5-2 keV flux limit. I will present number counts estimates apportioned by source classifications (AGNs and normal galaxies) and their subpopulations (e.g., redshift, AGN absorption, luminosity, and galaxy morphology), and I will discuss implications for models that describe the SMBH accretion history and X-ray evolution of normal galaxies. I will conclude by highlighting the potential for even deeper observations.

105.03 – **Early-type Galaxies: Among the Faintest X-ray Sources in the CDF-S**

Ann E. Hornschemeier[1]

[1]*NASA GSFC.*

10:46 AM - 11:08 AM

The ever-increasing depth of X-ray surveys raises the possibility of detecting extremely X-ray faint source populations, including the X-ray faint early-type galaxy population. Such a population of galaxies presents the opportunity to study the long-term evolution of low-mass X-ray binary (LMXB) populations. To this end, we have assembled a sample of ~ 400 low-luminosity early-type galaxies over $0.05 < z < 1.2$ in the three deep Chandra surveys (the CDF-S, E-CDF-S and CDF-N). Even with the 4 Ms Chandra Deep Field coverage currently available, the deepest survey of the extragalactic sky ever conducted at X-ray wavelengths, the vast majority of these galaxies (>90%) are undetected, so our work relies heavily on stacking analysis. We compare our observational constraints with new theoretical models

and discuss possibilities for future deep X-ray observations.

105.04 – **The Catalog, Mass Calibration and Statistical Properties of X-ray Galaxy Groups in CDFS**

Alexis Finoguenov[1]

[1]*MPE, Germany.*

11:08 AM - 11:30 AM

Studies of the X-ray emission from intergalactic medium have implications on the both gravitation heating and feedback at the mass scales relevant to galaxy evolution. Since the likely cause of feedback - black holes - are more active at high redshifts, surveys of distant galaxy groups are of particular value.

Recent ultra-deep observations of CDFS with Chandra and XMM-Newton have enabled the search of the extended X-ray emission down to a level 10,000 times fainter than the pioneering studies with ROSAT all sky survey. In parallel, extensive imaging surveys and large spectroscopic surveys at ESO and Magellan have been completed, enabling photometric and spectroscopic identification of galaxy groups to high redshifts.

We present the search for the extended emission in both Chandra and XMM data, and our efforts on the spectroscopic identification of sources, which results in a catalog of 40 spectroscopically identified groups, reaching a redshift of 1.6. We present the one and two point statistics, and stacked weak lensing calibration of Lx. We demonstrate that extrapolation of the scaling relations derived on COSMOS is capable to describe the statistical properties of the groups, constraining departures from the relation to be within 30% in mass.

106 – Clouds, Dust, and HII Regions

Oral Session – Room 3, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

106.01 – **Modeling Dust And Starlight In Galaxies Observed By Spitzer And Herschel: Ngc628 And Ngc6946**

Gonzalo J. Aniano Porcile[1], B. T. Draine[1], KINGFISH

[1]*Princeton University.*

10:00 AM - 10:10 AM

We present physical models for the interstellar dust in NGC628 and NGC6946, two well-resolved spiral galaxies observed by the IRAC and MIPS cameras on the Spitzer Space Telescope, and the PACS and the SPIRE cameras on the Herschel Space Observatory. Using the Draine, Li(2007) dust model, for each pixel in each galaxy we estimate the mass surface density of dust, the fraction of the dust mass contributed by polycyclic aromatic hydrocarbons (PAH)s, the distribution of the intensities of starlight that heat the dust grains, the total infrared (IR) luminosity emitted by the dust exposed to/heated by the starlight, and the IR luminosity originating in regions with high starlight intensity. We obtain well resolved maps for the dust properties, which trace the spiral structure of the galaxies. The dust models successfully reproduce the observed global and resolved spectral energy distributions (SEDs). We obtain total dust masses for each galaxy by summing the dust mass over the individual map pixels. These dust masses are consistent (within 10%) with the masses inferred from a model fit to the global photometry. The overall dust/H mass ratio estimate is consistent with what is expected for galaxies of near-solar metallicity. We do not find any evidence for significant masses of cold dust T<12K, potentially detectable when we include SPIRE (250-500um) photometry in our modeling. Discrepancies between the PACS and MIPS photometry result in large uncertainties when the modeling is done at PACS resolutions, in which case SPIRE, MIPS70um and MIPS160um data cannot be used. Therefore we do not recommend attempting to model dust in the outer parts of galaxies at the angular resolution of PACS. In a subsequent work we extend the present analysis to the remaining 59 galaxies of the project Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel (KINGFISH).

106.02 – **An Hst Multi-band Mapping Of Dust Extinction In The Nuclear Region Of M31**

Zhiyuan Li[1], H. Dong[2], M. Morris[1], Q. D. Wang[3]

[1]*University of California, Los Angeles,* [2]*NOAO,* [3]*University of Massachusetts.*

10:10 AM - 10:20 AM

The Andromeda galaxy (M31) provides an ideal laboratory for studying a galactic nuclear environment. We present a study of dust extinction in the central few hundred parsecs of M31, using recently available WFC3 and ACS images in ten bands ranging from near-UV to near-IR. We will discuss the morphology and fine structures of the dusty gas under sub-parsec resolutions, the extinction law in a spatially-resolved fashion, and implications on the physical regulation of the circumnuclear ISM.

106.03 – **Ablation from High Velocity Clouds: A Source for Low Velocity Ionized Gas**

Robin L. Shelton[1], D. B. Henley[1], K. Kwak[1]

[1]*Univ. of Georgia.*

10:20 AM - 10:30 AM

High velocity clouds shed material as they move through the Galaxy. This material mixes with the Galactic interstellar medium, resulting in plasma whose temperature and ionization levels are intermediate between those of the cloud and those of the Galaxy. As time passes, the mixed material slows to the velocity of the ambient gas. This raises the possibility that initially warm (T ~ 10^3 K), poorly ionized clouds moving through hot (T ~ 10^6 K), very highly ionized ambient gas could lead to mixed gas that harbors significant numbers of high ions (O+5, N+4, and C+3) and thus helps to explain the large numbers of low-velocity high ions seen on high latitude lines of sight through the Galactic halo.

We have used a series of detailed FLASH simulations in order to track the hydrodynamics of warm clouds embedded in hot Galactic halo gas. These simulations tracked the ablated material as it mixed and slowed to low velocities. By following the ionization levels of the gas in a time-dependent fashion, we determined that the mixed material is rich in O+5, N+4, and C+3 ions and continues to contain these ions for some time after slowing to low velocities. Combining our simulational results with estimates of the high velocity cloud infall rate leads to the finding that the mixed gas can account for ~ 1/3 of the normal-velocity O+5 column density found on high latitude lines of sight. It accounts for lesser fractions of the N+4 and C+3 column densities. We will discuss our high velocity cloud results as part of a composite halo model that also includes cooling Galactic fountain gas, isolated supernova remnants, and ionizing photons.

106.04 – **A Close Look At The Relationship Between WMAP (ILC) Small-Scale Features And Galactic HI Structure**

Gerrit L. Verschuur[1]

[1]*University of Memphis.*

10:30 AM - 10:40 AM

Galactic HI emission profiles surrounding two pairs of features located where large-scale filaments at very different velocities overlap were decomposed into Gaussian components. Families of components defined by similarity of center velocities and line widths were identified and found to be spatially related. Each of the two pairs of HI peaks straddle a high-frequency continuum source revealed in the WMAP survey data. It is suggested that where filamentary HI features are directly interacting high-frequency continuum radiation is being produced. The previously hypothesized mechanism for producing high-frequency continuum radiation involving free-free emission from electrons in the interstellar medium, in this case created where HI filaments interact to produce fractional ionizations of order 5 to 15%, fit the data very closely. The results confirm that WMAP data on small-scale structures believed to be cosmological in origin are in fact compromised by the presence of intervening galactic sources of interstellar electrons clumped on scales typical of interstellar HI structure.

106.05 – **Spitzer Observations of H II Regions in NGC 6822 and the Hot Star - H II Region Connection**

Robert H. Rubin[1], J. A. Kader[1], V. Sivaraja[1], J. P. Simpson[2], A. W. A. Pauldrach[3], R. J. Dufour[4], S. W. J. Colgan[1], I. A. McNabb[1], S. Y. Zhuge[1], V. Kalyanasundaram[1]

[1]*NASA Ames Research Center,* [2]*SETI Institute,* [3]*University of Munich, Germany,* [4]*Rice University.*

10:40 AM - 10:50 AM

We observed several H II regions in the dwarf irregular galaxy NGC 6822 using the Infrared Spectrograph (IRS) on the Spitzer Space Telescope. Measurements of [S IV] 10.51, [Ne II] 12.81, [Ne III] 15.56, and [S III] 18.71 micron emission lines were made in each of the H II regions. The lines were observed cospatially using the IRS in the short wavelength, high resolution mode, which permits a reliable comparison of the line fluxes. From the measured line fluxes we determine ionic abundance ratios including Ne++/Ne+ and S3+/S++. These ionic abundance ratios allow an analysis of the Ne/S ratio by taking the ratio of the dominant ionization states of the respective elements, Ne (Ne++, Ne+) and S (S3+, S++). Our aim here is twofold:

(1) to examine the Neon to Sulfur abundance ratio in order to determine whether or not it is fairly universal and

(2) to discriminate and test the predicted ionizing spectral energy distributions (SEDs) from various stellar atmosphere models by comparing our observational data

with H II region models that use these SEDs as input. This work extends our previous similar studies of H II regions in M83 and M33 to lower metallicities (and higher ionization), where we can attain a more reliable estimate of the Ne/S ratio. For the first time, we employ the new grid of SEDs from Pauldrach and Weber that have been computed with different metallicities: solar, 0.4 solar, and 0.1 solar. We demonstrate the effect on our analysis of changing just the stellar atmosphere model abundances. As expected, these changes to the SED show similar trends as does changing just the metallicities in the nebular gas abundances in our plasma simulations. Lower metallicity results in higher ionization.

Support from 09-ADP09-0169 and Spitzer 40910 are gratefully acknowledged.

106.06 – **Shocked and Scorched: Free-Floating Evaporating Gas Globules and Star Formation in Cygnus**

Raghvendra Sahai[1], M. J. Claussen[2], M. R. Morris[3]

[1]*JPL,* [2]*NRAO,* [3]*UCLA.*

10:50 AM - 11:00 AM

We report molecular line observations of a new class of Free-floating Evaporating Gas Globules with tadpole shapes (i.e., FrEGGs), recently discovered in the Cygnus star-forming region. We serendipitously found two of these in an HST imaging survey, including one of the most prominent members of this class (IRAS20324+4057: the Tadpole). Our molecular-line observations, carried out with the Arizona Radio Observatory's mm-wave telescopes, include on-the-fly maps in the CO and 13CO J=2-1 lines as well as pointed observations in the J=3-2 line of the high-density tracers HCO+ and N2H+. These data show the presence of dense molecular cores with total masses of cold molecular gas exceeding one to a few Msun in almost all FrEGGs. Our radio continuum imaging of 3 FrEGGs, as well as

Halpha images from the IPHAS survey reveal bright photo-ionized peripheries around these objects. We infer that FrEGGs are dense, star-forming molecular cores that originated in the Cygnus cloud and are now being photoevaporated by the ultraviolet radiation field of the Cyg OB2 cluster, and shaped by the ram pressure of strong wind sources. The extended tails in some of the largest objects show wiggles likely resulting from Kelvin-Helmoltz instabilities. We find evidence for non-thermal radio emission in the Tadpole, with the radio emission peaking strongly along the shock/ionization front at its head, possibly as a result of a compressed magnetic layer in this front that is interacting with cosmic rays associated with the Cyg OB2 association.

107 – Laboratory Astronomy and Pan-STARRS

Oral Session – Room 1, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

107.01 – **Measurements of the Astrophysically Important 40Ca(α,γ)44Ti Reaction**

Daniel Robertson[1], J. Gorres[1], P. Collon[1], H. Becker[2], M. Wiescher[1]
[1]*University of Notre Dame,* [2]*Ruhr-Universitat Bochum, Germany.*
10:00 AM - 10:10 AM

Observational studies of galactic γ-emitters such as ^{44}Ti ($t_{1/2}$ = 58.9 ± 0.3 yrs) have highlighted their use in nucleosynthesis studies of massive stars both in their late stage stellar evolution and final explosive demise in core collapse supernova events. Models used in the simulation of such γ emitters rely heavily upon reliable reaction rates for both the creation and annihilation of these isotopes over large temperature ranges. The production of ^{44}Ti mainly through the ^{40}Ca(α,γ)^{44}Ti reaction is thought to take place mostly in the α-rich freeze out phase of a core collapse supernova. However, current supernova model simulations predict lower ^{44}Ti to ^{56}Ni ratios than observed, creating a need for more information about its production mechanism. A number of previous experimental studies include prompt γ-ray measurements, recoil mass separator experiments and the use of accelerator mass spectrometry, all giving greatly different reaction rates. The results of experiments at the RUBION laboratory, Bochum and NSL, Notre Dame have allowed for greater constraints to be placed on reaction rates when compared to previous measurements. Acknowledgment and thanks to the support of the National Science Foundation (grant number PHYS-58100) and the Joint Institute for Nuclear Astrophysics (grant number PHY08-22648).

107.02 – **Reaction Rate Calculations in Dense Stellar Matter**

Mary Beard[1], E. Brown[2], L. Gasques[3], R. Lau[2], H. Schatz[2], M. Wiescher[1], D. Yakovlev[4]
[1]*University of Notre Dame,* [2]*Michigan State University,* [3]*University of Sao Paulo, Brazil,* [4]*University of St. Petersburg, Russian Federation.*
10:10 AM - 10:20 AM

Pycnonuclear fusion processes take place in the extreme density conditions anticipated to exist in the cores of white dwarfs and the crusts of neutron stars. Accurate modelling of pycnonuclear reactions is essential for understanding energy generation and transport in neutron stars. Calculation of pycnonuclear fusion rates strongly relies on knowledge of reaction cross sections. In most cases relevant cross section data is not availble and as such, cross section models must be used that are validated when ever possible by experimental measurements. Recently a formalism for calculating pycnonuclear reactions was developed for isotopes between boron and silicon. The pycnonuclear reaction rates will be presented and the results of the nucleosynthesis simulations will be discussed.

This work was supported by the Joint Institute for Nuclear Astrophysics (NSF-PHY-0822648).

107.03 – **St. George, a Recoil Separator for Nuclear Astrophysics at Notre Dame**

Manoel Couder[1], G. P. A. Berg[1], S. Devi[2], J. Görres[1], J. Hinnefeld[2], D. Robertson[1], E. Stech[1], M. Wiecher[1]
[1]*University of Note Dame,* [2]*Indiana University South Bend.*
10:20 AM - 10:30 AM

Radiative capture of proton or alpha nuclei play a crucial role in most stellar environments. The study of those reactions in the laboratory has been very successful since the early days of nuclear astrophysics. The standard experimental method is the detection of the gamma-rays characteristic of a radiative capture reaction induced by a proton or Helium beam on a stable target. However cosmic, environmental and beam induced background hamper measurement at low energy where the cross section is the most relevant. Moreover, the standard method does not allow the study of reaction involving unstable nuclei. An alternative technique consists of reversing the reaction, i.e. bombarding a hydrogen or Helium target with a heavy beam. The products of reaction and the beam that did not interact in the target are, after the target, contained in a narrow forward cone. A recoil separator is then used to transport the products of reaction in a detection system while the beam is deflected. The detection of the charged reaction product is more efficient than gamma-ray detection and is not affected by the standard background. Moreover, this method allows studies of reaction involving radioactive ions. At the Nuclear Science Laboratory of the University of Notre Dame, a recoil mass separator, St. George, has been designed and constructed. St. George will allow the study of Helium radiative capture by induced stable ions. This device is particularly well suited to measure cross section at low energy due to its large angular and energy acceptance. A new accelerator dedicated to the acceleration of ions with mass up to 50 is presently under commissioning and will be coupled to St. George.

This work is supported by the National Science Foundation under Grants No. PHY01-40324 and PHY08-22648, the Joint Institute for Nuclear Astrophysics.

107.04 – **Pan-STARRS1 Science Mission, Status and Results**

Kenneth C. Chambers[1]
[1]*Univ. of Hawaii.*
10:30 AM - 10:40 AM

Pan-STARRS1 began the PS1 Science Mission May 13, 2010. Operations of the PS1 System include the Observatory, Telescope, 1.4 Gigapixel Camera, Image Processing Pipeline , PSPS relational database and reduced science product software servers. The PS1 Surveys include: (1) A 3pi Steradian Survey; which current has obtained more than 30 epochs in 5 passbands (grizy) of the entire sky north of Dec = -30, or 30,000 square degrees with 0.26 arcsecond pixels, or nearly 2 Petabytes of images; (2) A Medium Deep survey of 10 PS1 footprints spaced around the sky or a total of 70 square degrees; (3) A solar system ecliptic plane survey optimized for the discovery of Near Earth Objects and Kuiper Belt Objects, (4) a Stellar Transit Survey of ~50 square degrees in the galactic buldge; and (5) a Deep Survey of M31 with special attention to a proper cadence for microlensing.

The performance of the PS1 system, sky coverage, cadence, and data quality of the images, the photometric calibration, and astrometric precision will be presented. Early science ranging from the solar system, brown dwarfs, galactic structure, supernovae, and galaxy counts will be presented. The completion of the PS1 Survey, the status of PS2 and plans for a PS1+PS2 Mission will be briefly addressed.

107.05 – **The Pan-STARRS-1 Outer Solar System Key Project**

Matthew J. Holman[1], P. Protopapas[1], Y. Chen[2], H. Lin[2], T. Grav[3], D. Ragozzine[1], Pan-STARRS-1 Science Consortium
[1]*Harvard-Smithsonian, CfA,* [2]*National Central University, Taiwan,* [3]*Planetary Sciences Institute.*
10:40 AM - 10:50 AM

The Pan-STARRS-1 survey has completed two years of full scale scientific operations. Roughly 60% of the observing time of the Pan-STARR-1 telescope is dedicated to a survey with an observing cadence that is suitable for the detection of slow-moving solar system bodies. We have developed an independent software pipeline that is optimized for the detection of such bodies at and beyond the distance of Jupiter. With this pipeline, the Pan-STARRS-1 survey will yield an essentially complete census of outer solar system bodies (Centaurs,comets, and trans-neptunian objects) brighter than magnitude r=22 to r=22.5. We present an update on the results of this survey and the outer solar system investigations it has enabled.

108 – Student Ideas, Teacher Training, and Public Outreach

Oral Session – Room 2, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

108.01 – **Investigating Undergraduate Student Ideas about Cosmological Concepts**

Kimberly A. Coble[1], L. E. Trouille[2], J. M. Bailey[3], C. T. Camarillo[1], M. D. Nickerson[1], G. L. Cochran[4], V. L. Hayes[1], K. M. McLin[5], L. R. Cominsky[5]
[1]*Chicago State University,* [2]*Northwestern University,* [3]*University of Nevada Las Vegas,* [4]*Florida International University,* [5]*Sonoma State University.*
10:00 AM - 10:10 AM

As scientists seek to understand the nature of our Universe, we can also explore our students' understanding of cosmological concepts. We will describe an ongoing study in which students' pre-instructional ideas are examined. Approximately 1000 students have responded to open-ended questions at the start of their introductory astronomy courses. Analysis of the responses, through an iterative process of identifying self-emergent themes, suggests that students have a number of common ideas. In addition to the open-ended written surveys administered at multiple institutions, additional data from a single minority-serving institution includes in-depth student interviews, homework assignments, lab responses, and exams gathered throughout an introductory astronomy course. Results are consistent with the surveys at the beginning of the course and indicate that while students do make strides toward scientific understanding over the semester, they frequently retain some critical misunderstandings. Furthermore, results indicate that using authentic lab experiences with "real" data can address the common student pre-course ideas that scientific conclusions are simply "made up." This presentation will give an overview of our methodologies and the results for student ideas on the composition of the Universe, including dark matter and dark energy. Also see our associated presentations on student ideas of structure and distances (Camarillo et al.) and age, expansion and the Big Bang (Trouille et al.). This work was supported by NASA ROSES E/PO Grant #NNX1OAC89G, as well as by the Illinois Space Grant Consortium and National Science Foundation CCLI Grant #0632563 at Chicago State University and the Fermi E/PO program at Sonoma State University.

108.02 – **Student Ideas about Cosmological Concepts: Structure and**

Distances

Carmelita Camarillo[1], K. Coble[1], L. E. Trouille[2], J. M. Bailey[3], M. D. Nickerson[1], G. L. Cochran[4], V. L. Hayes[1], V. L. Hayes[1], K. M. McLin[5], L. R. Cominsky[5]
[1]*Chicago State University,* [2]*Northwestern University,* [3]*University of Nevada Las Vegas,* [4]*Florida International University,* [5]*Sonoma State University.*
10:10 AM - 10:20 AM

Cosmology is a field of study that is rapidly advancing our current knowledge of the Universe. As the field advances, it is of interest to study how student ideas relate to scientific understanding. We describe an on-going study pertaining to students' cosmological concepts of structure and distances. The study was conducted in an urban minority-serving institution's Basic Astronomy course. The students who take this course have a diverse background of majors. Through a repeated measures design, student ideas regarding structure and distances are collected

from the beginning to the end of the course. The instruments implemented are homework essays, pre-tests surveys (before lab), exams (after lab), lab comments, and individual interviews. Students hold an array of mental representations and ideas about the Universe's structure and distances at the start of the course. Several of these different ideas may be based on misinterpreting scales or pictures. As the course continues, students tend to change several of their cosmological concepts to be more in line with scientific understanding. For instance, final exams tend to show a slightly better understanding of the Universe compared to initial homework essays and exams. However, individual interviews and other data reveal that some previous ideas regarding structure and distance can persist and may interfere with learning. Also see our presentations on student ideas of expansion and the Big Bang (Trouille et al.) as well as the overview of our methodology (Coble et al.). This work was supported by NASA ROSES E/PO Grant #NNX1OAC89G, as well as by the Illinois Space Grant Consortium and National Science Foundation CCLI Grant #0632563 at Chicago State University and the Fermi E/PO program at Sonoma State University.

108.03 – **Student Ideas About Cosmological Concepts: Age, Expansion, and the Big Bang**

Laura Trouille[1], K. Coble[2], C. Camarillo[2], J. Bailey[3], M. Nickerson[2], G. Cochran[4], V. Hayes[2], K. McLin[5], L. Cominsky[5]
[1]*Northwestern University CIERA Postdoctoral Fellow,* [2]*Chicago State University,* [3]*Univ. of Nevada Las Vegas,* [4]*Florida International University,* [5]*Sonoma State University.*
10:20 AM - 10:30 AM

Students enter introductory astronomy classes with ideas about the universe that are often misaligned with accepted scientific beliefs. In this presentation we will describe the results from a multi-semester study of urban minority students' ideas in an introductory astronomy course. We use in-depth student interviews, homework assignments, lab responses, and exams to identify pre-instructional ideas. We also examine the resilience of alternate conceptions to modification through instruction. In this presentation we focus on students' ideas with regards to the Big Bang, the age of the Universe, and the expansion of the Universe over time. We find that a significant fraction of students enter our astronomy courses with alternate conceptions, including that the Big Bang refers to an explosion from a small, single point in space, that there is no evidence for the Big Bang, that there is a center to our Universe, that the Universe expands into pre-existing matter, and that the Universe has either a much smaller or much larger age than its accepted age. Some of these alternate conceptions are relatively easy to overcome through active learning (for example, whether there is a center to the Universe), while others are more resistant to change (for example, whether the Universe expands into pre-existing matter). Also see our presentations on student ideas of structure and distances (Camarillo et al.) as well as the overview of our methodology (Coble et al.). This work was supported by NASA ROSES E/PO Grant #NNX1OAC89G, as well as by the Illinois Space Grant Consortium and National Science Foundation CCLI Grant #0632563 at Chicago State University and the Fermi E/PO program at Sonoma State University.

108.04 – **General Education Astronomy Students' Worldviews And Beliefs About The Role Of Science In Society: Initial Results**

Colin Scott Wallace[1], E. E. Prather[1], J. Teske[1], M. Meyers[1], B. Mendelsohn[2], Collaboration of Astronomy Teaching Scholars (CATS)
[1]*University of Arizona,* [2]*University of Cape Town, South Africa.*
10:30 AM - 10:40 AM

Over the past year, we began a new research project to uncover general education astronomy students' worldviews, their ideas about the role science plays in society, and the effects instruction has on these beliefs. Over the course of the spring 2012 semester, we collected students' written responses to several open-ended, provocative questions that investigate students' ideas about the impact science has had on areas such as the economy, their daily lives, and their fundamental beliefs about the nature of reality. This talk will present our preliminary findings from this project. This material is based upon work supported by the National Science Foundation under Grant No. 0833364 and 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.

108.05 – **NASA Education Activity Training (NEAT): Professional Development for Montana K-12 Teachers**

Kathryn Williamson[1], D. McKenzie[1], A. Des Jardins[1], J. Key[1], C. Kanode[1], S. Willoughby[1]
[1]*Montana State University.*
10:40 AM - 10:50 AM

Piloted during the 2011-2012 academic year, the NASA Education Activity Training (NEAT) teacher workshop program has introduced five solar astronomy and space weather activities to over forty Montana K-12 teachers. Because many Montana schools are geographically isolated (40% of Montana students live more than 50 miles from a city) and/or serve traditionally underrepresented groups (primarily Native Americans), professional development for teachers can be costly and time consuming. However, with funding shared by the Atmospheric Imaging Assembly EPO team and the Montana Space Grant Consortium, graduate student specialists are able to host the two-hour NEAT workshops on-site at the schools free of charge, and participating teachers earn two continuing education credits. Leveraging the existing catalogue of research-based NASA activities, the featured NEAT activities were chosen for their ease-of-use and applicability to Montana science standards. These include three advanced activities for older students, such as a paper plate activity for the June 5th, 2012 Transit of Venus, Kinesthetic Astronomy, and the Herschel Infrared experiment, along with two simpler activities for the younger students, such as Solar Cookies and the Electromagnetic War card game. Feedback surveys show that NEAT workshop participants were interested and engaged in the activities and planned on using the activities in their classrooms. With such positive responses, the NEAT program has been a huge success and can serve as a model for other institutions looking to increase their space public outreach and education.

108.06 – **Encouraging A Culture Of Outreach In Astronomy Clubs: Findings From The Astronomical Society Of The Pacific, The Institute For Learning Innovation, And Inverness Research**

Jim Manning[1], E. Jones[2], M. St. John[3], M. Berendsen[1], G. Schultz[1], S. Gurton[1], V. Yocco[2], P. Castori[3], J. Santascoy[1], V. White[1], K. Frank[1]
[1]*Astronomical Society of the Pacific,* [2]*Institute for Learning Innovation,* [3]*Inverness Research.*
10:50 AM - 11:00 AM

Astronomy clubs constitute a "marching army" of knowledgeable and experienced astronomy enthusiasts deployed in a national network: an enormously valuable and important resource for engaging the public through educational outreach events and activities. The Astronomical Society of the Pacific (ASP) in partnership with the Institute for Learning Innovation (ILI) and Inverness Research, Inc., has been engaged in a multi-year NSF-supported project focusing on this network and its potential to advance common astronomy education and outreach objectives. The project has explored the culture of astronomy clubs, identified impediments to building cultures of outreach within clubs, and developed and introduced new mechanisms to overcome these impediments and enhance clubs' abilities to encourage and sustain cultures that value and promote outreach efforts. The presenter will share initial research, development and evaluation findings of the project, and describe ongoing supplemental efforts that continue to advance project objectives.

109 – Interior

Oral Session – Room 4, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

109.01 – **Subsurface Supergranular Vertical Flows as Measured Using Large Distance Separations in Time-Distance Helioseismology**

Thomas L. Duvall, Jr.[1], S. M. Hanasoge[2]
[1]*NASA Goddard Space Flight Center,* [2]*Max-Planck-Institut fur Sonnensystemforschung, Germany.*
10:00 AM - 10:15 AM

As large-distance rays (say, 10-24 deg) approach the solar surface approximately vertically, travel times measured from surface pairs for these large separations are mostly sensitive to vertical flows, at least for shallow flows within a few Mm of the solar surface. All previous analyses of supergranulation have used smaller separations and have been hampered by the difficulty of separating the horizontal and vertical flow components. We find that the large separation travel times associated with supergranulation cannot be studied using the standard phase-speed filters of time-distance helioseismology. These filters, whose use is based upon a refractive model of the perturbations, reduce the resultant travel time signal by at least an order of magnitude at some distances. More effective filters are derived. Modeling suggests that the center-annulus travel time difference in the separation range 10-24 deg is insensitive to the horizontally diverging flow from the centers of the supergranules and should lead to a constant signal from the vertical flow. Our measurement of this quantity for the average supergranule, 5.1 s, is constant over the distance range. This magnitude of signal cannot be caused by the level of upflow at cell centers seen at the photosphere of 10 m/s extended in depth. It requires the vertical flow to increase with depth. A simple Gaussian model of the increase with depth implies a peak upward flow of 240 m/s at a depth of 2.3 Mm and a peak horizontal flow of 700 m/s at a depth of 1.6 Mm.

109.02 – **Helioseismic Measurements of Emerging Magnetic Flux in the Solar Convection Zone**

Stathis Ilonidis[1], J. Zhao[1], A. Kosovichev[1], T. Hartlep[1]

[1]*Stanford University.*

10:15 AM - 10:30 AM

Solar magnetic fields are probably generated deep inside the convection zone and then emerge to the surface and form active regions. Helioseismology is capable of probing acoustic perturbations in the solar interior by cross-correlating oscillation signals observed at the surface. In this study, we employ the time-distance helioseismology technique, and for several active regions observed with SOHO/MDI, SDO/HMI and GONG instruments investigate variations of the acoustic cross-correlation signals and phase travel-time shifts caused by emerging magnetic structures as deep as 65,000 km and 1-2 days before these structures appear at the surface. We discuss optimization of the time-distance method for the detection of emerging flux, present characteristics of the helioseismic signatures, and make comparisons with numerical simulations. We also investigate the relationship between the helioseismic signals and properties of the emerged active regions, and discuss perspectives for utilizing this method to improve space weather forecast.

109.03 – **Physics of Sunquakes Events Observed with SDO**

Alexander G. Kosovichev[1]

[1]*Stanford Univ..*

10:30 AM - 10:45 AM

Sunquake events representing helioseismic response to solar flares are caused by strong localized impacts in the low atmosphere during the flare impulsive phase. Several mechanisms of the impact have been debated, but there is no clear understanding of how energy and momentum are transported from the magnetic energy release site (presumably located in the higher atmosphere) to the solar surface. It is also puzzling why some moderate class flares produce sunquakes, while significantly more powerful flares do not. Observations with SDO have substantially improved our ability to investigate details of the helioseismic response and the impact source properties and dynamics, providing data with high spatial and temporal resolutions, as well as spectro-polarimetric properties. I will present new results on several sunquake events observed with the HMI and AIA instruments and discuss the basic properties of the helioseismic waves, their interaction with active regions, the source dynamics and its relation to the amplitude and direction of the waves. The observations also reveal interesting relationships between the sunquake impacts, X-ray and white-light emissions and magnetic field changes in solar flares. I will compare the observational results with the physical models of sunquakes (thick-target model, McClymont jerk, backwarming, mass eruption), and discuss model constraints from the new observations.

109.04 – **Testing Helioseismic Measurements Of Subsurface Meridional And Large-scale Flows Using Artificial Data From Numerical Simulations**

Thomas Hartlep[1], J. Zhao[1], A. G. Kosovichev[1], N. N. Mansour[2]

[1]*Stanford University,* [2]*NASA / Ames Research Center.*

10:45 AM - 11:00 AM

Numerical simulations of the solar acoustic wave-field have become an important tool for validating helioseismic measurement and inversion techniques. Here, we present results from simulating linearized wave propagation in the full 3D solar interior through stationary flow fields, and measurements applied to this artificial data. The background flow include different meridional flow models with deep and shallow return flows, as well as a full-resolution snapshot from a solar convection simulation in anelastic approximation using the "ASH" code, provided to us by Mark Miesch. Time-distance helioseismology measurements and inversions are carried using this artificial data and the results are compared to the models. We determine and discuss the accuracy and resolution of the subsurface flow patterns.

109.05 – **Searching For Equator-ward Meridional Flows In The Solar Interior**

Junwei Zhao[1], R. S. Bogart[1], A. G. Kosovichev[1], T. L. Duvall, Jr.[2]

[1]*Stanford Univ.,* [2]*NASA Goddard Space Flight Center.*

11:00 AM - 11:15 AM

At what depth the equator-ward meridional flow exists and what is its speed are important questions for a better understanding of solar dynamo and a better prediction of how active a solar cycle is. However, the depth and the speed of the equator-ward flow are still not determined from helioseismology after studies of more than one decade. The new high-resolution observations from HMI has offered us a new chance to tackle these problems. Moreover, the systematic center-to-limb variation that was recently found in time-distance helioseismology analysis probably implies that the equator-ward flows exist in areas much shallower than the tachocline. Utilizing two years' HMI observations, we examine how well we can determine the depth and speed of the returning meridional flow.

109.06 – **Comparison of Numerical and Observational Scattering of the f-mode by Small Magnetic Elements**

Tobias Felipe[1], D. C. Braun[1], A. D. Crouch[1], A. C. Birch[2]

[1]*NorthWest Research Associates,* [2]*Max Planck Institut fur Sonnensystemforschung, Germany.*

11:15 AM - 11:30 AM

The observed scattering of the f-mode by small magnetic elements is studied through Fourier-Hankel analysis and compared with three-dimensional numerical simulations of the scattering produced by magnetic flux tube models. The numerical setup consists of an f-mode wave packet which is propagated through a realistic solar atmosphere embedded with a flux tube model. A quiet Sun simulation without a tube present is also performed as a reference. Sausage (m=0) and kink (m=±1) modes are excited in the flux tube and propagate along the field lines, and jacket modes are generated in the surroundings of the flux tube, carrying 40% as much energy as the tube modes. The resulting scattered wave is mainly an f-mode composed of a mixture of m=0 and m=±1 modes. We find the observed dependence of the phase shift with wavenumber for an ensemble average of about 3400 magnetic elements can be matched reasonably well with the simulated flux tube model. The observed variation with azimuthal order m of the phase-shifts appears to depend on details of the ensemble averaging, including possible motions of the magnetic elements and asymmetrically shaped elements.

This research has been funded by NASA through projects NNH09CE43C, NNH09CF68C, and NNH07CD25C.

110 – Solar Magnetism & the Activity Cycle I

Oral Session – Room 5, Dena'ina Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

110.01 – **Simulating the Rise of Low Twist Flux Ropes in the Convection Zone**

Mark Linton[1], J. Leake[2]

[1]*NRL,* [2]*George Mason University.*

10:00 AM - 10:15 AM

Simulations of magnetic flux emergence are now well established, but work well only for highly twisted flux ropes. Weakly twisted ropes fragment as they rise through the convection zone, and if they make it to the surface, they then flatten out against the photosphere rather than emerging. However, vector magnetic field observations of sunspots show that on average the twist of sunspots is orders of magnitude lower than that of these simulated emerging flux ropes. We present the results from a study, with magnetohydrodynamical simulations, investigating the rise of minimally buoyant twisted flux ropes from the deep convection zone to the photosphere. We establish limits, in this regime, on the minimum twist that a flux rope needs to survive this convection zone transit without breaking up and ceasing to rise. We discuss the implications of these results, as compared with observations of the twist in active regions, on our current understanding of how active regions rise to the solar surface and emerge into the solar atmosphere.

110.02 – **Observational Criteria For Small-scale Turbulent Dynamo In The Solar Photosphere**

Valentyna Abramenko[1], P. Goode[1], V. Yurchyshyn[1]

[1]*Big Bear Solar Observatory.*

10:15 AM - 10:30 AM

Generation and dispersal of the magnetic field on the Sun is a key mechanism responsible for solar activity on all spatial and temporal scales - from the solar cycle down to the evolution of small-scale magnetic elements in the quiet Sun. The solar dynamo operates as a non-linear dynamical process and is thought to be manifested in two types: as a global dynamo responsible for the solar cycle periodicity, and as a small-scale turbulent dynamo (SSTD) responsible for the formation of magnetic carpet in the quiet Sun. Numerous MHD simulations of the solar turbulence did not yet reach a consensus as to the existence and role of SSTD on the Sun. At the same time, high-resolution observations of the quiet Sun are capable to provide certain criteria to prove or rule out SSTD. We suggest to probe four possible criteria: i) mutual behaviour of the kinetic and magnetic power spectra; ii) intermittency/multifractality of the magnetic field; iii) smallest observed scale of magnetic flux tubes; iv) regime of magnetic diffusivity on smallest observable scales. We analyse magnetic, velocity and solar granulation data as derived from Hinode/SOT, SOHO/MDI, SDO/HMI and the New Solar Telescope (NST) of Big Bear Solar Observatory (BBSO) to explore the possibilities for SSTD in the quiet Sun.

110.03 – **Solar Cycle Variations of Sunspot Magnetic Field Strengths from the Mount Wilson Observatory**

Alexei A. Pevtsov[1], L. Bertello[1], A. Tlatov[2], Y. Nagovitsyn[2], A. Kilcik[3]

[1]*National Solar Observatory,* [2]*Pulkovo Observatory, Russian Federation,* [3]*Big Bear Solar Observatory.*

10:30 AM - 10:45 AM

We used historical synoptic data the Mount Wilson Observatory (MWO) to study long-term changes in sunspot magnetic field strengths over the period of 1920-1959. By selecting sunspots with the strongest field strength for each observing day, we find that the average field strengths in sunspots vary with solar cycle with amplitude of a few hundred Gauss. The data show no statistically significant long-term trend over the period of about 40 years covered by these observations. We also find that the fractional distribution of sunspots changes from cycle to cycle. From Cycle 15 to Cycle 19, MWO data show a steady increase in fraction of sunspots with weaker field strengths (<1000 G), while the fraction of sunspots with strongest field strengths (>3000 G) steadily decreases. The fraction of sunspots with field strengths between 1000-3000 Gauss does not change in any systematic way. In contract, the fractional distribution of sunspots by their area (i.e., small, intermediate, and large) taken from the Greenwich observatory data set does not change during the same period of time. The different behavior in these two fractional distributions might indicate some physical changes in the properties of sunspots (e.g., sunspots of about the same area show progressively smaller field strengths), or it could be the result of some systematic instrumental/observational effects. We discuss our findings in the framework of these two possible explanations.

110.04 – **Decreasing Sunspot Magnetic Fields Explain Unique 10.7cm Radio Flux**

Matthew J. Penn[1], W. Livingston[1], L. Svalgaard[2]
[1]*National Solar Obs.,* [2]*HEPL.*
10:45 AM - 11:00 AM

Infrared spectral observations of sunspots from 1998-2011 have shown that on average sunspots changed; the magnetic fields weakened and the temperatures rose. The data also show that sunspots or dark pores can only form at the solar surface only if the magnetic field strength exceeds 1500 Gauss. Sunspots appear at the solar surface with a variety of field strengths, and during the period from 1998-2002 a histogram of the sunspot magnetic fields shows a normal distribution with a mean near 2400 Gauss and a width of about 340 Gauss. During this observing period the mean of the magnetic field distribution decreased by about 64 Gauss per year, and we assume that as the 1500 Gauss threshold was approached, magnetic fields appeared at the solar surface which could not form dark sunspots or pores With this assumption we propose a quantity called the *sunspot formation fraction* and give an analytical form derived from the magnetic field distribution. We show this fraction can quantitatively explain the changing elationship between sunspot number and solar radio flux measured at 10.7cm wavelengths.

110.05 – **Circumfacular Regions in Ca II 854.2 nm**

Anna Pietarila[1], J. Harvey[1]
[1]*National Solar Observatory.*
11:00 AM - 11:15 AM

Active regions appear bright in Ca II 854.2 nm line core intensity while the surrounding areas, circumfacular regions, are darker than the active region or the quiet Sun. We use SOLIS VSM Ca II 854.2 nm data (high spectral resolution Stokes I and V profiles as well as photospheric and chromospheric LOS magnetograms) to study the relationship between the atmospheric dynamics, LOS magnetic field stratification and detailed spectral line properties, e.g., line bisectors and Stokes V asymmetries. The presence of circumfacular regions, magnetic canopies and flows may explain the solar cycle variation of Sun-as-star Ca II 854.2 nm bisectors.

110.06 – **Photospheric Magnetic Flux Transport - Supergranules Rule**

David H. Hathaway[1], L. Rightmire-Upton[2]
[1]*NASA/MSFC,* [2]*Univ. Alabama, Huntsville.*
11:15 AM - 11:30 AM

Observations of the transport of magnetic flux in the Sun’s photosphere show that active region magnetic flux is carried far from its origin by a combination of flows. These flows have previously been identified and modeled as separate axisymmetric processes: differential rotation, meridional flow, and supergranule diffusion. Experiments with a surface convective flow model reveal that the true nature of this transport is advection by the non-axisymmetric cellular flows themselves - supergranules. Magnetic elements are transported to the boundaries of the cells and then follow the evolving boundaries. The convective flows in supergranules have peak velocities near 500 m/s. These flows completely overpower the superimposed 20 m/s meridional flow and 100 m/s differential rotation. The magnetic elements remain pinned at the supergranule boundaries. Experiments with and without the superimposed axisymmetric photospheric flows show that the axisymmetric transport of magnetic flux is controlled by the advection of the cellular pattern by underlying flows representative of deeper layers. The magnetic elements follow the differential rotation and meridional flow associated with the convection cells themselves - supergranules rule!

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111 – High Angular Resolution Sunyaev-Zel'dovich Effect

Special Session – Summit Hall 2, Egan Center – 6/11/2012 10:00:00 AM to 6/11/2012 11:30:00 AM

A host of sensitive new millimeter and submillimeter telescopes are opening frontiers in the study of Galaxy Clusters by enabling unprecedentedly detailed measurements of the Sunyaev-Zel'dovich Efffect (SZE). These telescopes include the GBT, CARMA, ALMA, and soon SCUBA-2, the LMT, CSO+MUSIC, and CCAT. Fueled by these capabilities and the emergence of SZE-selected cluster samples from ACT, SPT and Planck, interest in this area has been rapidly increasing over the past few years. The focus of this session will be on detailed astrophysical studies of clusters using the SZE and on targeted studies of the SZE aiming to maximize the inferences we can make from cluster surveys. It will also include theoretical and multi-wavelength perspectives.

111.01 – **What We Have Learned About Clusters From a Decade of Arcsecond-resolution X-ray Observations**

Maxim L. Markevitch[1]
[1]*Harvard CfA/NASA GSFC.*
10:09 AM - 10:18 AM

This talk will briefly review the main findings from Chandra high angular resolution observations of galaxy clusters, emphasizing results on cluster astrophysics. Chandra has discovered shock fronts in merging systems, providing information on the shock Mach number and velocity, and for best-observed shocks, constraining the microphysical properties of the intracluster medium (ICM). Cold fronts, a Chandra discovery, are ubiquitous both in merging clusters and in the cool cores of relaxed systems. They reveal the structure and strength of the intracluster magnetic fields and constrain the ICM viscosity. Combined with radio data, these observations also shed light on the production of ultrarelativistic particles that are known to coexist with thermal plasma. Finally, in nearly all cool cores, Chandra observes cavities in the ICM that are produced by the central AGN. All these phenomena will be extremely interesting for high-resolution SZ studies.

111.02 – **From High Resolution Maps to Large Area Cluster Surveys: MUSTANG2 on the Green Bank Telescope and the Atacama Cosmology Telescope (ACT)**

Mark J. Devlin[1]
[1]*Univ. of Pennsylvania.*
10:18 AM - 10:27 AM

Clusters of galaxies are the largest gravitationally bound objects in the Universe. They represent a rich astrophysical laboratory for studying interactions on a wide range of scales. Studies of how and when clusters form yield important cosmological constraints. The MUSTANG and ACT instruments provide a full range of angular scale the measurements that utilize the SZ effect to study clusters.

111.03 – **PLANCK+MUSTANG SZ**

Anna Scaife[1]
[1]*University of Southampton, United Kingdom.*
10:27 AM - 10:36 AM

It has been proposed that the over-representation of disturbed and merging systems in SZ-selected cluster samples is due to a bias in the selection function of these samples towards such objects. Characterizing this bias, and the processes responsible for it, is important for cosmological applications using cluster data from low resolution SZ observations, such as that from the Planck satellite. High resolution SZ observations towards objects which have been detected for the first time in the Planck all-sky catalogue will provide detail on high energy non-gravitational processes within these clusters by probing inhomogeneities in the pressure sub-structure of the intra-cluster medium. I will discuss a sample of such clusters which have been observed with the MUSTANG camera on the Green Bank Telescope and their implications for cluster cosmology.

111.04 – **Probing Cluster Physics with High-Resolution SZE Imaging and Simulations**

Daisuke Nagai[1]
[1]*Yale University.*
10:36 AM - 10:45 AM

High-resolution Sunyaev-Zel'dovich (SZ) experiments are frontiers for studying the structure and evolution of galaxy clusters across cosmic time. However, because dynamical process of cluster formation is highly non-linear, design and interpretation of these experiments require guidance from detailed numerical simulations. In this talk, I will present results of high-resolution hydrodynamical simulations of galaxy cluster formation, with highlights on their rich thermal and velocity structures that could be probed by the upcoming SZ experiments.

111.05 – **Unveiling the Complex Physical Processes of the ICM with High-Res SZ Observations**

Nicholas Battaglia[1]
[1]*Carnegie Mellon University.*
10:45 AM - 10:54 AM

Using galaxy clusters selected by the Sunyaev Zel'dovich (SZ) effect for precision cosmology requires understanding the detailed astrophysical processes of the intracluster medium (ICM). High resolution SZ maps of clusters are starting to probe these processes on larger scales and with finer detail than has been possible. From mock observations of a large sample of simulated clusters, I present the potential for these observations to measure (important physical effects like) clumping and pressure profiles in cluster outskirts. Additionally, I will show the capacity for these SZ maps to further constrain cluster mass proxies and the SZ power spectrum.

111.06 – **SLAM High Resolution Numerical Simulations of the SZ Signatures of Cluster Mergers**

Craig L. Sarazin[1], M. Chatzikos[1], B. W. O'Shea[2]
[1]*Univ. of Virginia,* [2]*Michigan State Univ..*
10:54 AM - 11:03 AM

I present the results of high resolution simulations of the effects of cluster mergers on SZ observations. Most of the simulations are from the SLAM (Simulation Library of Astrophysical galaxy cluster Mergers) library of 156 binary cluster mergers. These simulations include cluster masses ranging from 1e13 to 2e15 Msun, and mass ratios for the mergers of 1:1 to 10:1. They include four values of the dimensionless angular momentum of the merger (lambda = 0.0, 0.025, 0.05, and 0.075), ranging from head-on mergers to high impact parameter collisions. Many of the SZ features correspond to shocks and/or adiabatic compression events. The effect of these transient SZ features on the use of clusters to measure cosmological parameters in surveys is assessed.

Support for this work was provided by Chandra grants TM7-8010X, GO9-0135X, GO9-0148X, GO1-12159A, and GO1-12169X, through NASA Suzaku grants

NNX09AH25G and NNX09AH74G, through NASA ADAP grant NNX11AD15G, through NASA ATFP grant #08-ATFP08-0028, through NSF AST grant #0908819, and Michigan State University's Institute for Cyber-Enabled Research. Computer time was provided by NSF TeraGrid grants TG-AST080001N and TG-AST090040.

111.07 – **Measuring the Sunyaev-Zel'dovich Effect with CARMA: Past, Present, and Future**

Thomas J. Plagge[1]

[1]*University of Chicago.*

11:03 AM - 11:12 AM

The Combined Array for Research in Millimeter-wave Astronomy (CARMA) is a 23-element heterogeneous interferometer capable of measuring the Sunyaev-Zel'dovich effect over a large angular dynamic range. An upgrade currently in progress will enhance its utility as an SZ instrument, allowing the array to be configured for significantly higher sensitivity at the most relevant angular scales. I will briefly discuss the scientific motivation for resolved SZ imaging, give an overview of CARMA's current capabilities, and report on the status of the upgrade. I will also show examples of SZ data obtained from the existing array, reviewing the relevant imaging techniques and comparing our results to previous measurements.

111.08 – **Measurement of the Sunyaev-Zeldovich Effect Increment with Large Aperture Sub-mm Telescopes**

Michael Zemcov[1]

[1]*California Institute of Technology.*

11:12 AM - 11:21 AM

Measurement of the Sunyaev-Zeldovich (SZ) effect increment is critical for precision determination of the full spectrum of the SZ spectral distortion, which in turn is necessary for measurement of the relativistic and kinetic SZ effects that are largest shortward of the SZ null at 217 GHz. Maps of galaxy clusters at SZ increment frequencies have the added benefit of relatively high angular resolution, allowing a precise determination of the sub-mm galaxy contamination in clusters, which is a significant foreground to SZ spectral studies. Current and upcoming facilities including SPIRE, SCUBA-2, MUSIC on the CSO, and further in the future next generation instrumentation for CCAT, will provide extremely deep, high angular resolution, multi-band SZ spectrum measurements in many clusters. Such measurements will enable new types of SZ science, including detailed studies of the properties of the intra-cluster medium and line of sight velocity effects. In this talk I will review the status of measurements of the SZ increment, present new results from Herschel, and look forward to what developments we can expect over the coming years.

111.09 – **Sunyaev-Zeldovich Effect Science with CCAT**

Sunil R. Golwala[1]

[1]*California Institute of Technology.*

11:21 AM - 11:30 AM

CCAT will be the next major submillimeter/millimeter-wave single-dish observatory, to be sited on Cerre Chajnantor at 5600 m. It is being designed with a wide field-of-view (1 degree) and a broad suite of imaging and spectroscopic instrumentation. We discuss the prospects for science involving the Sunyaev-Zeldovich (SZ) effect, specifically imaging of the thermal, relativistic, and kinetic SZ effects in galaxy clusters at angular resolutions of 0.2-0.4 arcmin. CCAT will offer an unprecedented spatial and spectral dynamic range for cluster studies, extending from the virial radius into the cluster core and from 740 microns to 2 to 3 mm. In conjunction with lensing and X-ray data, CCAT will be able to measure cluster masses more precisely than previously possible, with implications for cosmological parameter determination, and study the entropy and non-thermal pressure profile of the intracluster medium (ICM) and turbulence therein. The relativistic SZ effect will provide the mass-weighted ICM temperature. The kinetic SZ effect will enable the study of cluster peculiar velocities, bulk motions of the ICM, and constraints on the length of the reionization epoch. With CCAT's deep submm imaging capability, the contributions of dusty star-forming galaxies to flux in SZ bands can be estimated and removed and early hints of correlations between thermal SZ and the cosmic infrared background can be elucidated. A broad consortium with substantial experience from prior submm/mm instruments is proposing a multiwavelength imager, LWCam, the enable these science goals.

112 – SPD Hale Prize: The Two Sources of Solar Energetic Particles

Invited Session – Ballroom B, Dena'ina Center – 6/11/2012 11:40:00 AM to 6/11/2012 12:30:00 PM

112.01 – **The Two Sources of Solar Energetic Particles**

Donald V. Reames[1]

[1]*University of Maryland.*

11:40 AM - 12:30 PM

The identification of two different physical mechanisms for acceleration of solar energetic particles (SEPs) began nearly 50 years ago with the radio observations of type III bursts produced by outward streaming electrons and type II bursts from coronal (and interplanetary) shock waves. Since that time we have found that the former are related to "impulsive" SEP events from flares or jets where resonant stochastic acceleration, probably related to magnetic reconnection, can produce 1000-fold enhancements of ^{3}He/^{4}He and of (Z>50)/O, for example, while the latter "gradual" SEP events sample ion abundances democratically and are used to measure the coronal abundances of the elements. Sometimes, unfortunately, residual impulsive suprathermal ions can also contribute to the seed population for shock acceleration, complicating the picture, but this process can now be modeled theoretically. Initially, impulsive events behave like a point source on the Sun, while multi-spacecraft observations of gradual events show extensive acceleration that can span half of the inner heliosphere, beginning when the shock reaches ~2 solar radii. Acceleration occurs as ions are scattered back and forth across the shock by proton-generated resonant Alfven waves. These waves also define a streaming-limited maximum intensity or plateau region prior to arrival of the shock. Behind the shock lies an extensive "reservoir" region of spatially uniform SEP intensity that decreases with time as the "magnetic bottle" enclosing it expands.

113 – NSF Town Hall

Town Hall – Ballroom A, Dena'ina Center – 6/11/2012 12:45:00 PM to 6/11/2012 1:45:00 PM

Personnel from the NSF Division of Astronomical Sciences will discuss the implementation of the response to the Astro2010 decadal survey, implications of the FY12 budget and FY13 budget request, the status and completion plans for the NSF Portfolio Review, and other topical information on NSF grants and facilities that is of interest to the AAS community.

114 – Bridging Laboratory & Astrophysics: Atoms

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying atomic processes which drive our cosmos.

114.01 – **X-ray Diagnostics of Astrophysical Plasmas**

Randall K. Smith[1]

[1]*Smithsonian Astrophysical Observatory.*

2:00 PM - 2:30 PM

High-resolution X-ray data from current X-ray satellites exposes the need for high-quality atomic data of all stripes: wavelengths, collisional/radiative rates, and absorption cross sections. Astro-H will increase the available effective area for high-resolution at some energies by orders of magnitude, bringing the issue into sharp relief. I will describe the successes of both theoretical calculations and laboratory measurements, as well as the many remaining needs and the science that hinges upon them. These include, amongst other issues, accurate wavelength measurements in the soft X-ray band, well-calibrated diagnostic ratios of select lines, and high-resolution absorption cross sections for abundant ions.

114.02 – **Accurate Spectral Modeling of Fe II. A Long Standing Problem in Astrophysics**

Manuel Bautista[1]

[1]*Western Michigan University.*

2:30 PM - 3:00 PM

Fe II is one of the most common atomic species in astronomical UV, visible, and IR spectra. Its rich spectrum, observable in essentially every class of astronomical objects, makes this ion a potentially powerful source of plasma diagnostics as well as a standard metalicity indicator. Yet, the Fe II remains poorly understood owing to insufficiently accurate atomic data and complex excitation mechanisms. In this talk, I overview the different applications of Fe II spectral modeling in astronomy. I also review the most important advances in the field and the challenges remaining. Finally, I discus the prospects of building a satisfactory model of the ion in the near future.

114.03 – **Laboratory Oscillator Strengths for Studies of Fe-group Abundances**

Elizabeth Den Hartog[1]

[1]*University of Wisconsin.*

3:00 PM - 3:30 PM

Recent decades have seen significant improvement in both the quantity and quality of available oscillator strengths for lines in the first and second spectra of many elements. These improvements have led to an increase in both the precision and accuracy of stellar abundance determinations, which in turn help elucidate outstanding questions in stellar astrophysics. One such outstanding question arises in the study of Fe-group nucleosynthesis in the early Universe. The observed trends of relative Fe-group abundances as a function of stellar metallicity (or age) are seriously discordant (~1 dex) with Solar values and are difficult to replicate with nucleosynthetic yield calculations and models. These unexplained trends may

result from some combination of residual errors in oscillator strengths, non-LTE/3D photospheric effects, and/or poorly understood nuclear physics. To help shed light on these outstanding questions we have returned our focus to the Fe-group atoms and ions, beginning with Mn I and Mn II. The goal of this ongoing work is to provide very accurate (< ± 0.02 dex) oscillator strengths for Fe-group elements over a wide range of excitation potential for both neutral and singly ionized transitions such that both Saha and Boltzmann equilibrium assumptions can be tested. Abundance studies in metal poor giant and dwarf stars using these oscillator strengths indicate that while the resonance lines of the neutral yield Mn abundances that are too low compared to other neutral and ion transitions, the other transitions all yield consistent Mn abundances and [Mn/Fe] values of -0.70 ± 0.20 dex at metallicities of [Fe/H] = -2.5 ± 0.3. In metal-poor stars, the findings of subsolar Fe-group relative abundances appear to be robust. There is also a pressing need for Fe-group oscillator strengths for transitions in the H-band in support of APOGEE. Current work on Fe I will be described.

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115 – Multiple Populations in Globular Clusters: Evidence & Latest Results

Meeting-in-a-Meeting – Ballroom C, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

This session focuses on the spectroscopic and photometric evidence for multiple populations in globular clusters, including the range of population properties and how common this phenomenon might be.

115.01 – **Multiple Populations in Globular Clusters: Spectroscopic Evidences and the Horizontal Branch Second Parameter Issue**

Raffaele Gratton[1]

[1]*Osservatorio Astronomico di Padova, Italy.*

2:00 PM - 2:22 PM

A wealth of recent data indicate that globular clusters hosts multiple stellar populations. Spectroscopy allows a deep insight into their very early phases of formation. Also, they

allow to clarify long standing issues like the second parameter affecting the morphology of the horizontal branch. We found that this is due to a combination of mainly two effects: variations in the age of individual clusters and the existence of populations with different He abundances within clusters. We discuss direct and indirect evidences for this.

115.02 – **Metallicity Trends in Supermassive Clusters**

William E. Harris[1]

[1]*McMaster University, Canada.*

2:22 PM - 2:44 PM

"Supermassive" globular clusters can be thought of as ones above the million-Solar-mass level. Within the Local Group, such objects are quite rare (w Cen and M31-G1 are the best known examples). Photometric surveys of globular cluster systems in giant and supergiant galaxies now indicates that in this supermassive regime of 10^6-107 Solar masses, the classic bimodal distribution of color/metallicity breaks down. Instead, they display a broad and more uniform distribution of colors which may well be the result of early self-enrichment during their formation phase. Consistent with these observations, simple but dynamically motivated models show that such extremely massive protoclusters should be capable of holding back enough of their own early enriched SNe ejecta to self-enrich the low-mass stars during formation.

115.03 – **High Precision Differential Chemical Abundance Measurements**

David Yong[1]

[1]*Australian National University, Australia.*

2:44 PM - 3:06 PM

A signature of multiple populations in a given globular cluster is large chemical diversity for particular elements. Much effort has been devoted to identifying and characterising such abundance inhomogeneity.

Arguably, an equally important step in studying the chemical abundance patterns in globular clusters is to examine the elements which do not show a star-to-star abundance variation to constrain the chemical homogeneity. Using a strictly differential approach, we show that particular elements in some globular clusters are homogeneous at the 0.01 dex level (2%).

115.04 – **The Chemistry of Multiple Populations in Old Stellar Clusters**

Eugenio Carretta[1]

[1]*Osservatorio Astronomico di Bologna, Italy.*

3:06 PM - 3:28 PM

The complex nature of Globular Clusters has recently revealed that they host more than a Simple Stellar Population. In recent years, evidence of peculiar chemical composition and presence of multiple stellar generations has been found, on the basis of spectroscopic and photometric studies. I will review the observational evidence and its bearings on the cluster formation and early evolution mechanism, focusing on the chemical signature of multiple populations.

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116 – Extragalactic Gamma-ray Background (EGB): Contribution From Unbeamed Sources and Dark Matter Constraints

Meeting-in-a-Meeting – Summit Hall 4, Egan Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

The origin of the Isotropic Gamma-ray Background (IGRB) is one of the fundamental unsolvedproblems in astrophysics. The intensity of this isotropic radiation has been measured with precision by Fermi and found to be compatible with a featureless power law up to 100 GeV.Its nature is however still enigmatic. Blazars, active galactic nuclei with a relativistic jetclosely aligned to the line of sight, are the most numerous population detected at gamma-rays and represented for a long time the primary candidate to explain the IGRB emission. However, there are evidencethat they do contribute ≤30% of the IGRB. Leaving the remaining ~70% unexplained.The second session of this meeting will focus on the contribution of un-beamed sourcesof gamma-ray like star-forming galaxies and on the use of the IGRB spectrum to constrain scenarios of dark matter annihilation into GeV gamma-rays.

116.01 – **The Impact of Electromagnetic Cascades of Very-high Energy Gamma Rays on the Extragalactic Gamma-ray Background**

Tonia M. Venters[1]

[1]*Goddard Space Flight Center.*

2:00 PM - 2:15 PM

As very high energy (VHE) photons propagate through the extragalactic background light (EBL), they interact with the soft photons of the EBL and initiate electromagnetic cascades of photons and electrons. The collective intensity of a cosmological population emitting at VHEs (such as blazars) will be attenuated at the highest energies through interactions with the EBL and enhanced at lower energies by the resulting cascade. As such, depending on the space density and spectra of the sources and the model of the EBL, cascade radiation can provide a significant contribution to the extragalactic gamma-ray background (EGB). Through deflections of the charged particles of the cascade, an intergalactic magnetic field (IGMF) may leave an imprint on the anisotropy properties of the EGB. The impact of a strong IGMF is to isotropize lower energy cascade photons, inducing a modulation in the anisotropy energy spectrum of the EGB. We discuss the implications of cascade radiation for the origins of the EGB and the nature of the IGMF, as well as insight that will be provided by data from the Fermi Large Area Telescope in the upcoming years.

116.02 – **The Gamma-Ray Background from Star-Forming Galaxies**

Brian D. Fields[1]

[1]*Univ. of Illinois.*

2:15 PM - 2:30 PM

The process of massive star formation gives rise supernova explosions, which in turn launch strong shocks, which are the sites of cosmic-ray acceleration. Cosmic-ray interactions with interstellar matter and photons unavoidably give rise to gamma rays. Thus, star-forming galaxies are a guaranteed source of the extragalactic gamma-ray background as observed by Fermi. We present a calculation of the gamma-ray background from normal star-forming galaxies, including hadronic and leptonic emission as well as the effects of core-collapse and Type Ia supernovae. We find that the resulting signal can represent a substantial and perhaps dominant component of the Fermi background. We briefly comment on future tests of this result, and discuss its implications for using gamma rays to probe cosmic rays over cosmological history.

116.03 – **Contribution of Unresolved Galaxies to the Extragalactic Diffuse Gamma-ray Background**

Keith Bechtol[1]

[1]*Stanford.*

2:30 PM - 2:45 PM

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.

116.04 – **Extragalactic Gamma-ray Background (EGB): Contribution From**

Fermi-LAT Blazars and Dark Matter Constraints

Vahe Petrosian[1]
[1]*Stanford Univ..*
2:45 PM - 3:00 PM

Fermi has accumulated a large sample of blazars with known fluxes and spectral indexes based on a single power law fit to observed photon counts from which one can obtain the distribution of the indexes, the flux distribution (i.e. what is commonly called the log *N*-log *S* relation). The results can then be used to determine the contribution of blazars to the diffuse Extragalactic Gamma-ray Background (EGB) radiation. However, since harder spectra can be detected to lower fluxes than the softer ones the observational selection process introduces a bias in this bi-variate distribution which truncates the data severely at low fluxes and and softer spectra. We have used the non-parametric method described by Efron and Petrosian to correct the data for this truncation and obtained the true mono-variate distributions. With our method we can also obtain the blazar contribution to EGB also non-parametrically. The results when extrapolated to lowest possible fluxes can give the contribution of all blazars to EGB and indicate what fraction of EGB could be due to dark matter annihilation or decay or other astronomical sources. We will present our result applied to a sample of LAT blazars consisting of 352 sources and describe its implication for the extragalactic background gamma-ray radiation.

116.05 – **Dark matter constraints from the Fermi/LAT Extragalactic Gamma-ray Background and the role of halo substructure**

Miguel Angel Sanchez-Conde[1]
[1]*KIPAC/SLAC, Stanford University.*
3:00 PM - 3:15 PM

After almost four years of operation, Fermi/LAT has measured the Extragalactic Gamma-ray Background (EGB) with unprecedented sensitivity, furthermore extending, for the first time, the EGB spectrum down to 100 MeV and up to several hundred GeV. Although a large variety of extragalactic objects are expected to contribute to the EGB, according to recent estimates the sum of their different contributions is not enough to explain the measured EGB. Gamma-rays from annihilation products of supersymmetric dark matter (DM) particles may account for this missing emission. In this talk, I will discuss on the parameter space allowed for DM annihilation in the most recent EGB spectrum by Fermi/LAT. At present, the key ingredient in the determination of the expected contribution of DM annihilation to the EGB is the so-called substructure boost factor, thus special attention will be given to this parameter. Substructure boosts are related to the amount of DM subhalos hosted by larger DM halos. Up to now, attempts to precisely calculate it both analytically and/or making use of N-body cosmological simulations have failed due to the difficulty of examining in detail the properties of the smallest DM halos. Indeed, the DM contribution to the EGB can vary over several orders of magnitude depending on the assumed DM substructure model. Here, I will present a DM substructure model which is based on our current knowledge of DM halo formation and evolution in the framework of the state-of-the-art ΛCDM cosmological model. This model makes possible to confidently calculate substructure boosts for halos of different masses. After applying it, the uncertainty bands that bracket the contribution of DM annihilation to the EGB will become not only substantially narrower but also better physically motivated. The use of such a more sophisticated DM substructure model makes possible to assess other crucial EGB aspects as well.

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117 – New Horizons for Science From the Moon: Precision Measurements in Gravitational Physics

Meeting-in-a-Meeting – Ballroom A, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

The New Worlds, New Horizons Particle Astrophysics & Cosmology Panel of the Astro2010 Decadal Survey emphasized the unique role of the Moon where Lunar Laser Ranging (LLR) â€œoffers a promising and cost-effective way to test General Relativity and other theories of gravityâ€. The report recommended â€œdeploying a global, long-lived *LLR+ network on the Moon,â€ especially since the Apollo arrays have already demonstrated most of the best tests of GR. LLR is also complementary to the recently-launched GRAIL mission for studying the Moonâ€™s interior, providing more detailed data on the inner core region. In this session, recent advances in LLR will be presented including the first laser signals recovered from Lunokhod 1 and next generation retro-reflectors that may be emplaced on the Moon within the next few years by potential commercial spacecraft (Google Lunar X-Prize). This â€œLunar Laser Ranging Retroreflector for the 21st Centuryâ€ will increase the accuracy supported by the lunar emplacement by a factor of 10 to 100.

117.01 – **How and Where to Test General Relativity and Explore Gravitational Physics**

E Sterl Phinney[1]
[1]*Caltech.*
2:00 PM - 2:12 PM

We review the prospects for testing general relativity and its foundations and alternatives in the coming decade(s). These include lab, solar system, cosmological and astrophysical measurements, and direct detection of gravitational waves from the ground and from space. An attempt is made to evaluate whether and where the moon offers unique or cost-effective scientific opportunities.

117.02 – **Gravity Recovery and Interior Laboratory (GRAIL) Mission: Mission Status and Preliminary Science Results**

Maria Zuber[1], D. E. Smith[1], M. M. Watkins[2], D. H. Lehman[2], GRAIL Science Team
[1]*MIT,* [2]*JPL.*
2:12 PM - 2:24 PM

The Gravity Recovery and Interior Laboratory (GRAIL) Mission is a component of the NASA Discovery Program. GRAIL is a twin-spacecraft lunar gravity mission that has two primary objectives: to determine the structure of the lunar interior, from crust to core; and to advance understanding of the thermal evolution of the Moon. These broad objectives are addressed by mapping the gravity field of the Moon to provide the structure of the crust & lithosphere, help understand the Moon’s asymmetric thermal evolution, determine the subsurface structure of impact basins and the origin of mascons, ascertain the temporal evolution of crustal brecciation and magmatism, place constraints on the deep interior structure from tides, and place limits on the size of the possible inner core. As a secondary objective, GRAIL observations will be used to extend understanding of the internal structure and thermal evolution of other terrestrial bodies. GRAIL launched successfully from the Cape Canaveral Air Force Station on September 10, 2011, executed a low-energy trajectory to the Moon, and inserted the twin spacecraft into lunar orbit on December 31, 2011 and January 1, 2012. A series of maneuvers brought both spacecraft into low-altitude (55-km), near-circular, polar lunar orbits, from which they will perform high-precision satellite-to-satellite ranging using a Ka-band payload along with an S-band link for time synchronization. Analysis of the spacecraft-to-spacecraft range-rate data will provide a direct measure of the lunar gravity, leading to a high resolution (30x30 km), high-accuracy (<10 mGal) global gravity field. Science data collection is scheduled to begin on March 8, 2012 and continue for approximately three months. An initial gravity field will be available about 30 days after the end of the data acquisition phase.

117.03 – **Testing Gravity and Lunar Dust via Lunar Laser Ranging**

Thomas W. Murphy[1]
[1]*UC, San Diego.*
2:24 PM - 2:36 PM

Forty years ago, Apollo astronauts placed the first of several retroreflector arrays on the Moon. Laser range measurements between the Earth and the Moon have provided some of our best tests to date of general relativity and gravitational phenomenology--including the equivalence principle, the time-rate-of-change of the gravitational constant, the inverse square law, and gravitomagnetism. A new effort called APOLLO (the Apache Point Observatory Lunar Laser-ranging Operation) is now collecting measurements at the unprecedented precision of one millimeter, which will produce order-of-magnitude improvements in a variety of gravitational tests, as well as reveal more detail about the interior structure of the Moon. This talk will include an overview of the science goals, a demonstration of millimeter range performance, the re-discovery of the Lunokhod 1 reflector, and convincing evidence that the lunar reflectors are covered by dust.

117.04 – **Astrophysics and the Next Generation of Lunar Laser Ranging**

Douglas G. Currie[1], S. Dell'Agnello[2], G. Delle Monache[2], K. Zacny[3], B. Behr[4]
[1]*University of Maryland,* [2]*2.Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati, Italy,* [3]*3.Exploration Technology Group, Honeybee Robotics Spacecraft Mechanisms Corporation,* [4]*University of Maryland, College Park.*
2:36 PM - 2:48 PM

The unique science results addressing Gravitational Science and General Relativity (GR) that have been produced by the Lunar Laser Ranging Program (LLRP) to date will be described. While the Apollo retroreflector arrays are still operation and continue to produce new state-of-the-art science results, the combination of the lunar librations and the design of the arrays currently limit the range accuracy obtained for each single photo-electron return to ~20 mm. A next generation lunar retroreflector (e.g., the Lunar Laser Ranging Retroreflector for the 21st Century or LLRRA-21) holds promise for great improvements in the existing values on the various tests of General Relativity. This is critical due to: 1) the inconsistency between GR and Quantum Mechanics and 2) our lack of understanding of Dark Energy. These puzzles have engendered a variety of alternate theories of gravitation which need to be tested against GR. The magnitude of these improvements will depend critically on the method of robotic deployment of the LLRRA-21. The deployment will be reviewed, especially those that can be supported by the Google Lunar X Prize flights of the next couple of years. The expected magnitude of the return signal from the optical/thermal simulations will be described in detail. This expected signal return will be similar to signal return that is currently being obtained from the Apollo 15 array, so we can evaluate the capability of various ground stations to conduct regular ranging programs. This will address number of ground stations that can contribute and the frequency of observations what would be available for the science analysis. Finally, the lifetime issues related to the Apollo arrays and the projection to the current design of the LLRRA-21 will be discussed. This work has been supported by the LUNAR team of

the NASA/NLSI and the INFN-LNF and ASI.

117.05 – **Large-Scale Hollow Retroreflectors for Lunar Laser Ranging at Goddard Space Flight Center**

Alix M. Preston[1]

[1]*Goddard Space Flight Center.*

2:48 PM - 3:00 PM

Laser ranging to the retroreflector arrays placed on the lunar surface by the Apollo astronauts and the Soviet Luna missions have dramatically increased our understanding of gravitational physics along with Earth and Moon geophysics, geodesy, and dynamics. Although the precision of the range measurements has historically been limited by the ground station capabilities, advances in the APOLLO instrument at the Apache Point facility in New Mexico is beginning to be limited by errors associated with the lunar arrays. We report here on efforts at Goddard Space Flight Center to develop the next generation of lunar retroreflectors. We will describe a new facility that is being used to design, assemble, and test large-scale hollow retroreflectors. We will also describe results from investigations into various bonding techniques used to assemble the open corner cubes and mirror coatings that have dust mitigation properties.

117.06 – **MoonLIGHT, a Lunar Laser Ranging Retroreflector Array for the 21st Century, and the ASI-INFN Etrusco-2 project**

Giovanni O. Delle Monache[1], S. Dell' Agnello[1], D. Currie[2], M. Martini[1], R. Vittori[3], C. Cantone[1], A. Boni[1], S. Berardi[1], G. Patrizi[1], M. Maiello[1], M. Tibuzzi[1], M. Garattini[1], C. Lops[1], E. Ciocci[1], C. Graziosi[1], G. Bianco[1], N. Intaglietta[1]

[1]*INFN-LNF, Italy,* [2]*University of Maryland,* [3]*ESA-EAC, Germany.*

3:00 PM - 3:12 PM

Since the 1970s Lunar Laser Ranging (LLR)

to the Apollo Cube Corner Retroreflector (CCR) arrays supplied almost all

significant tests of General Relativity and significant

information on the composition and origin of the moon. In the 1970s Apollo LLR arrays contributed a negligible fraction of the ranging error budget. Since the ranging capabilities of ground stations improved by more than two orders of magnitude, now, because of the lunar librations, Apollo CCR arrays dominate the error budget. With the project MoonLIGHT in 2006 INFN-LNF joined UMD in the development and test of a new-generation LLR payload made by a single CCR unaffected by librations. In particular, INFN-LNF built and is operating a new experimental apparatus (SCF) and created a new industry-standard test procedure (SCF-Test) to characterize the thermal behavior and the optical performance of CCRs in simulated space conditions. Our key experimental innovation is the concurrent measurement and modeling of the optical FFDP and the temperature

distribution of retroreflector payloads under thermal conditions produced with a close-match solar simulator. These capabilities provide: unique pre-launch performance validation of the space segment of LLR/SLR. Results of the SCF-Test of our CCR payload will be presented. Negotiations are underway to propose our payload and SCF-Test

services for precision gravity and lunar science measurements with next robotic lunar landing missions. We will describe the addition of the CCR optical Wavefront Fizeau Interferogram (WFI) concurrently to FFDP/temperature measurements in the framework of an ASI-INFN project, ETRUSCO-2. The main goals of the latter are: development of a standard GNSS laser Retroreflector Array; a second SCF; SCF-Test of Galileo, GPS and other 'as-built' GNSS retroreflector payloads. Results on analysis of Apollo LLR data and search of new gravitational physics with LLR, Mercury Radar Ranging, SLR of LAGEOS (Laser GEOdynamics Satellite) will be presented

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118 – Galaxy Mergers from the Largest to the Smallest Scales: Large-Scale Structure and Merger Rates

Meeting-in-a-Meeting – Room 2, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

Galaxy mergers, including the mergers of their central SMBHs, take place on a vast range of time and distance scales. They can be observed at wavelengths spanning most of the electromagnetic spectrum, and through gravitational waves, and encompass a wide range of astrophysical phenomena. Two key areas have seen rapid progress recently. Current and upcoming large-scale spectroscopic, imaging, and transient surveys will be provide tight new constraints on merger statistics, will detect many more dual AGN, and may be sensitive to the newly predicted electromagnetic transients from coalescing BBHs. And, modeling the final SMBH coalescence and the resulting BH recoil has a wealth of potential astrophysical implications which are now being explored, including galaxy and BH evolution at the epoch of structure formation and unified models of active galaxies. This timely meeting combines all key aspects of galaxy mergers from large to small scales, and brings together experts from the different subfields.

This first session begins with an overview, and then examines properties of mergers on the largest scales.

118.01 – **Galaxy Mergers from the Largest to the Smallest Scales: Introduction and Overview**

Joan Centrella[1]

[1]*NASA's GSFC.*

2:00 PM - 2:30 PM

Galaxy mergers encompass a wide range of astrophysical phenomena, including cosmological considerations, gas and stellar dynamics, AGN evolution, and mergers of the central SMBHs. Astrophysical

signatures of galaxy mergers can be observed across most of the electromagnetic spectrum and through gravitational radiation. This talk provides an introduction and overview of the meeting, highlighting the key aspects of galaxy mergers from large to small scales.

118.03 – **The Evolution of AGN in Groups and Clusters of Galaxies**

Paul Martini[1]

[1]*The Ohio State University.*

3:00 PM - 3:20 PM

The distribution and evolution of AGN in dense environments provides constraints on the fueling of their central, supermassive black holes, the interplay between black hole and galaxy growth, and the evolution of feedback on both galaxies and the surrounding medium as a function of redshift. I will provide a brief overview of the demographics of AGN in groups and clusters, and in particular the evolution of the fraction of AGN that host luminous galaxies relative as a function of time, their spatial distribution, and how their properties compare with AGN in the lower-density field.

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119 – The Deepest View of the X-ray Universe: 4 Ms Chandra Deep Field Results II

Meeting-in-a-Meeting – Summit Hall 2, Egan Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

This session will cover recent results from the deepest X-ray survey of the Universe, theChandra Deep Field 4 Ms survey. The two 90-minute sessions begin with an overview ofX-ray surveys that have already taken place as well as a view of the future with newmissions such as NuSTAR and eROSITA. Speakers from a variety of topics ranging fromGalactic stars, high-redshift galaxies and galaxy groups will report on what this ultradeepview in the X-rays reveals. We envision a 30 minute overview talk on X-ray surveys,followed by a 15-minute description of the sources of the CDF-S (number counts andsource types). The second session will begin with a talk on normal galaxies whichare among the very faintest X-ray sources in the 4 Ms CDF-S.

119.01 – **A High Redshift Group of Quiescent Early-Type Galaxies in the Chandra Deep Field South**

Masayuki Tanaka[1], A. Finoguenov[2], M. Mirkazemi[2], J. Mulchaey[3], D. Wilman[4], N. Brandt[5], Y. Xue[5]

[1]*IPMU, Japan,* [2]*MPE, Germany,* [3]*Carnegie Observatory,* [4]*MPI, Germany,* [5]*Penn State University.*

2:00 PM - 2:24 PM

We report on a newly identified group of galaxies at z=1.61 in the Chandra Deep Field South. The group shows extended X-ray emission and the inferred mass of the system is a few times 10^{13} Msun. Based on the deep HST data from CANDELS, we find that the group galaxies exhibit a tight red sequence formed at z_f=3. Most of the group members are quiescent galaxies with little sign of on-going star formation. Furthermore, our GALFIT analysis shows that they are ealry-type galaxies. Our result may suggest that a group is a place for quiescent early-type galaxies since a very early epoch.

119.02 – **The Interplay of Massive Black Hole Growth and Galaxy Evolution**

C. Megan Urry[1]

[1]*Yale Univ..*

2:24 PM - 2:46 PM

The growth of black holes over billions of years releases energy that may quench star formation ("feedback") and strongly affect galaxy evolution. Using the deep Chandra data in the CDFS/ECDFS, we investigate the effects of moderate luminosity AGN on their host galaxies. Unlike quasars, these are the average galaxies in which most supermassive black holes grow and most stars form. At the peak epoch of black hole growth and star formation (> 5 billion years ago), we find evidence that AGN may help quench star formation (which is not the case in the local Universe). Perhaps surprisingly, most moderate luminosity AGN are hosted in galaxies with significant disks, even at the peak epoch, suggesting that major mergers do not trigger most black hole growth.

119.03 – **The Cosmic History of Black Hole Accretion from Chandra X-ray**

Stacking

Ezequiel Treister[1], C. Urry[2], K. Schawinski[2], N. Lee[3], P. Natarajan[2], M. Volonteri[4], D. B. Sanders[3]

[1]Universidad de Concepción, Chile, [2]Yale University, [3]University of Hawaii, [4]Institut d'Astrophysique de Paris, France.

2:46 PM - 3:08 PM

In order to fully understand galaxy formation we need to know when in the cosmic history are black holes growing more intensively, in what type of galaxies this growth is happening and what fraction of these sources are invisible at most wavelengths due to obscuration.

We take advantage of the rich multi-wavelength data available in the Chandra Deep Field South (CDF-S), including the 4 Msec Chandra observations (the deepest X-ray data to date), in order to measure the amount of black hole accretion as a function of cosmic history, from z~0 to z~6. We obtain stacked rest-frame X-ray spectra for samples of galaxies binned in terms of their IR luminosity, stellar mass and other galaxy properties. We find that the AGN fraction and their typical luminosities, and thus black hole accretion rates, increase with IR luminosity and stellar mass. The integrated intensity at high energies indicates that a significant fraction of the total black hole growth, 22%, occurs in heavily-obscured systems that are not individually detected in even the deepest X-ray observations. We find evidence for a strong connection between significant black hole growth events and major galaxy mergers from z~0 to z~3, while less spectacular but longer accretion episodes are most likely due to other (stochastic) processes.

E.T. and K.S. gratefully acknowledges the support provided by NASA through Chandra Postdoctoral Fellowship Award Numbers PF8-90055 and PF9-00069, respectively issued by the Chandra X-ray Observatory Center. E.T. also thanks support by NASA through Chandra Award SP1-12005X Center of Excellence in Astrophysics and Associated Technologies (PFB 06). C. M. Urry acknowledges support from NSF Grants AST-0407295, AST-0449678, AST-0807570, and Yale University.

119.04 – **Tracking Down the Source Population Responsible for the Unresolved Cosmic 6-8 keV Background**

Yongquan Xue[1], S. X. Wang[2], W. N. Brandt[2], B. Luo[3], D. M. Alexander[4], F. E. Bauer[5], A. Comastri[6], A. C. Fabian[7], R. Gilla[6], B. D. Lehmer[8], D. P. Schneider[2], C. Vignali[9], M. Young[2]

[1]University of Sciences and Technology of China, China, [2]Penn State University, [3]Harvard-Smithsonian CfA, [4]Durham University, [5]Pontificia Universidad Catolica de Chile/SSI, Chile, [6]Osservatorio Astronomico di Bologna, Italy, [7]Institute of Astronomy, United Kingdom, [8]Johns Hopkins University/NASA GSFC, [9]Universita di Bologna, Italy.

3:08 PM - 3:30 PM

We report preliminary results of efforts to track down the source population responsible for the unresolved 6-8 keV cosmic X-ray background (XRB). Using the 4 Ms Chandra Deep Field-South (CDF-S) survey, we have identified a sample of 5293 X-ray undetected galaxies that dominates the unresolved ~20-25% of the 6-8 keV XRB. This sample was constructed by applying mass and color cuts to sources from a parent catalog based on GOODS-South HST z-band imaging of the central 6-arcmin-radius area of the 4 Ms CDF-S. The stacked 6-8 keV detection is significant at the 4.3 sigma level, but the stacked emission was not detected in the 4-6 keV band which indicates the existence of an underlying population of highly obscured active galactic nuclei (AGNs). Further examinations of these 5293 galaxies indicate that the galaxies with redshifts of $1<z<2$, magnitudes of $25<z_{850}<27$, and masses of $4E8<M_{star}/M_{sun}<4E9$ make the majority contributions to the unresolved 6-8 keV XRB. Such a population is seemingly surprising given that the majority of the X-ray detected AGNs reside in massive ($>10^{10}$ M_{sun}) galaxies. We discuss constraints upon this underlying AGN population, supporting evidence for relatively low-mass galaxies hosting highly obscured AGNs, and prospects of further boosting the stacked signal. The results presented here are still preliminary. Further investigations are currently under way to verify the robustness of the results.

120 – Solar Systems I

Oral Session – Ballroom B, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

120.01 – **WISE Constraints on the Particle Properties in Saturn's Phoebe Ring**

Douglas P. Hamilton[1], M. F. Skrutskie[2], A. J. Verbiscer[2]

[1]Univ. of Maryland, [2]Univ. of Virginia.

2:00 PM - 2:10 PM

Saturn's diffuse outer Phoebe Ring is an immense disk-like structure oriented edge-on as viewed from Earth; it is 30 million km (500 Saturn radii) wide and 2.5 million km (40 Saturn radii) thick. The ring's particles are thought to originate from the planet's dark irregular satellites, primarily Phoebe (mean radius 107km) but also a handful of other moonlets with radii smaller than 10km. The ring was discovered by 24 micron imaging by Spitzer (Verbiscer et al., Nature 2009) and recently recovered by WISE (Skrutskie et al., DPS 2011) at 22 microns. The WISE images, which show the full extent of the ring for the first time, nicely complement the Spitzer data, which has better signal to noise. Usually, ring particle populations can be determined observationally from spectral and phase angle information, but as these observations are extremely limited, we instead rely on dynamical arguments. Small particles in the Phoebe ring are expected to be driven to eccentricities in excess of Phoebe's e=0.16 by radiation pressure over 30-year timescales. Over million-year timescales, the dust distribution migrates inward via Poynting-Robertson drag, and most of the material is delivered to Iapetus' dark side. We model these processes numerically and build up synthetic ring profiles, making various assumptions about the unknown particle size distribution. We produce radial intensity profiles which we compare to the WISE data as well as vertical profiles which are most constrained by Spitzer. Our procedure is more robust than the onion-peeling technique used by ring scientists because it does not require the assumption of circular orbits. We find that the ring is made up of particles between ~10 microns and a few centimeters in radius and will report on further constraints that arise from more detailed modeling of size distributions as well as potential asymmetries seen in the data.

120.02 – **Tidal Evolution of the Quaoar-Weywot System**

Wesley Fraser[1], M. E. Brown[2], K. Batygin[2], A. Bouchez[3]

[1]Herzberg Institute of Astrophysics, Canada, [2]California Institute of Technology, [3]Giant Magellan Telescope Observatory.

2:10 PM - 2:20 PM

In some ways, the Kuiper Belt binary system, Quaoar-Weywot, is quite similar to the the Eris-Dysnomia system. The primaries of both systems are large, and both systems have high mass ratios of $\sim 10^5$:1. Unlike Eris however, Quaoar appears to have an unexpectedly high mass, and therefore has a high density, p>3 g cm^{-3}. Furthermore, while Dysnomia is found on a nearly circular orbit, Weywot's orbit appears to have a high eccentricity, e~0.1. We will present new Keck adaptive optics observations of the Quaoar-Weywot system which confirm both Quaoar's high mass, of $1.3-1.4 \times 10^{21}$ kg and Weywot's eccentricity, e=0.13-0.16. We will present a reanalysis of the tidal orbital evolution of the Quoaor-Weywot system and contrast this with that of the Eris-Dysnomia system. From order-of-magnitude estimates, we find that with plausible values of the effective tidal dissipation factor for both bodies, tidal evolution is, at least in principle, compatible with the current orbits of Weywot and Dysnomia. That is, Dysnomia's orbital eccentricity will decay on very short timescales, while Weywot's eccentricity either remains constant, or evolves to higher values. Finally, we present tidal evolution simulations which demonstrate that, unless Quaoar were unusually non-dissipative, Weywot's eccentricity could not have tidally evolved to its current value from an initially circular orbit. Rather, some other mechanism has raised its eccentricity post-formation, or Weywot formed with a non-negligible eccentricity.

120.03 – **The Sunward Continuum Features of Comet 103P/Hartley 2**

Beatrice E. A. Mueller[1], N. H. Samarasinha[1], T. L. Farnham[2], M. F. A'Hearn[2]

[1]Planetary Science Institute, [2]Department of Astronomy, University of Maryland.

2:20 PM - 2:30 PM

Comet 103P/Hartley 2 had a very close approach to Earth and was successfully encountered by the EPOXI mission in 2010. We observed the comet with the Kitt Peak 2.1m telescope September 1-3, September 30 - October 4, November 2-8, and December 11-15 with broadband R and narrowband HB comet filters. Results on the structures seen in the CN coma were reported by Samarasinha et al. (2011). Here we present the analysis of the sunward continuum features (deduced from the broadband R filter).

The appearance and the spatial extent of the sunward continuum features are very different from those of the CN features. The sunward continuum features are often nearly radial with almost no apparent curvature. Rotational phase plots of the position angles of the sunward continuum features are consistent with the dominant periodicity derived from the concurrent CN features and the sunward features are present at nearly all rotational phases. We will derive basic physical parameters of the grains dominating the sunward continuum features using the fact that the spatial extent of these features is much smaller than that of the CN features and assuming that this is due to the solar radiation pressure effect.

This work was partly supported by a NASA Planetary Astronomy Grant.

References:

Samarasinha et al. 2011; ApJL 734, article id. L3.

120.04 – **Cometary Volatiles and Planetary System Origins**

Michael F. A'Hearn[1]

[1]University of Maryland.

2:30 PM - 2:40 PM

The very large ratio of CO_2/CO in comet 103P/Hartley 2 (A'Hearn *et al*. 2011, *Science* 332, 1396) coupled with the high ratios of CO_2/H_2O in many comets observed with the *AKARI* satellite (Ootsubo *et al*. 2012 in press) suggest rethinking the origin of comets. We note that the high abundances of CO_2 likely require reactions between CO and OH on the surfaces of icy grains. We will also argue that the Jupiter-family comets formed in a region substantially overlapping that of the dynamically new, long-period, and Halley-type comets, contrary to the commonly accepted picture. Planetary migration can then send them on different dynamical routes.

Numerous colleagues contributed in significant ways to this work. The work was funded by NASA.

120.05 – **Asymmetric Spherical Coupled Escape Probability: Model and Results for Optically Thick Cometary Comae**

Alan Gersch[1], M. F. A'Hearn[1]
[1]*Univ. of Maryland.*
2:40 PM - 2:50 PM

We have adapted the Coupled Escape Probability method of radiative transfer calculations for use in asymmetrical spherical situations and applied it to modeling molecular emission spectra of potentially optically thick cometary comae.

Recent space missions (e.g. Deep Impact & EPOXI) have provided spectra from comets of unprecedented spatial resolution of the regions of the coma near the nucleus, where the coma may be optically thick. Currently active missions (e.g. Rosetta) and hopefully more in the future will continue the trend and demonstrate the need for better modeling of comae with optical depth effects included.

Here we present a brief description of our model and results of interest for cometary studies, especially for space based observations.

Although primarily motivated by the need for comet modeling, our (asymmetric spherical) radiative transfer model could be used for studying other astrophysical phenomena as well.

120.06 – **Looking for Planets in all the Right Places**

Rosanne Di Stefano[1]
[1]*Harvard-Smithsonian CfA.*
2:50 PM - 3:00 PM

Gravitational lensing has the potential to discover planets in orbits of all sizes, orbiting both nearby and distant stars. Until recently, however, searches for planets via lensing have been conducted by programs best suited to finding only a subset of planetary lenses. During the past year several new approaches have been developed, including searches for small periodic signals near baseline, and monitoring nearby stars. By taking these approaches, we will extend our search for planets to *all* the right places, and will increase the discovery rate. In addition, the extended lensing searches will discover nearby planetary systems that can subsequently be observed using the full range of planet-study techniques, including transit and radial velocity studies as well as direct imaging. I will talk about the theory and also about preliminary results from our monitoring of the first predicted lensing event for evidence of planets orbiting the nearby dwarf star VB 10.

120.07 – **The KELT-North Transit Survey's First Planetary Detections**

Thomas G. Beatty[1], A. Bieryla[2], D. Cohen[3], K. Collins[4], J. Eastman[5], B. J. Fulton[5], B. Gary[6], B. S. Gaudi[1], L. Hebb[6], E. L. N. Jensen[3], D. W. Latham[2], M. Manner[7], J. Pepper[6], R. Siverd[6], K. Stassun[6], R. A. Street[5]
[1]*Ohio State University,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*Swarthmore College,* [4]*University of Louisville,* [5]*Las Cumbres Observatory Global Telescope Network,* [6]*Vanderbilt University,* [7]*Spot Observatory.*
3:00 PM - 3:10 PM

I will present the first planetary detections from the KELT-North transit survey. KELT-North is a 42mm robotic camera system at Winer Observatory in Arizona, and survey operations are based out of the Ohio State and Vanderbilt Universities. The KELT-North survey fields are 26 by 26 degrees, and are arranged in a contiguous strip around the sky centered at a declination of +30 degrees. The small aperture and wide field of view of the telescope enables KELT-North to effectively survey some of the brightest stars in the Northern sky for transiting planets. Our focus is on planet candidates around stars between 8 < V < 10. These bright systems are of prime scientific interest, since they provide the best follow-up opportunities from the ground and space. We have been collecting science data since 2006, and actively vetting planet candidates since the spring of 2011. Over the past winter we recorded our first detections of sub-stellar companions. I will briefly discuss KELT-North survey operations before describing the results from our observations of these intriguing systems. We are grateful to the observers and the support staff at the FLWO 60- and 48-inch telescopes. This work was supported by NSF CAREER grant AST-1056524.

120.08 – **Precision Near-Infrared Radial Velocities**

Peter Plavchan[1], G. Anglada[2], P. Gao[1], R. White[3], C. Davison[3], D. Ciardi[1], C. Beichman[1], K. Wallace[4], B. Mennesson[4], K. von Braun[1], G. Vasisht[4], M. Fitzgerald[5], I. McLean[5], C. Brinkworth[1], L. Prato[6], J. Johnson[1], S. Kane[1], B. Walp[7], A. Tanner[8], S. Crawford[4], S. Lin[1], S. Mills[1]
[1]*Caltech,* [2]*University of Goettingen, Germany,* [3]*Georgia State University,* [4]*Jet Propulson Laboratory, Caltech,* [5]*UCLA,* [6]*Lowell Observatory,* [7]*Gemini,* [8]*Mississippi State.*
3:10 PM - 3:20 PM

We have built a single gas absorption cell for precision spectroscopic radial velocity measurements in the near-infrared. We are currently carrying out a survey with the CSHELL spectrograph at the NASA InfraRed Telescope Facility to detect exoplanets around red, low mass, and young stars. We discuss the current status of our survey, with the aim of ~20 m/s long-term photon-noise limited radial velocity precision at 2.3 microns. We present the design of a near-infrared fiber scrambler with first light in May 2012 with CSHELL at IRTF. The fiber scrambler makes use of non-circular core fibers to stabilize the illumination of the slit and echelle grating against changes in seeing, focus, guiding and other sources of systematic radial velocity noise, complementing the wavelength calibration of a gas cell.

120.09 – **High-Contrast Imaging Follow-up of Radial Velocity Trend Stars**

Justin R. Crepp[1], J. A. Johnson[1], California Planet Search
[1]*California Institute of Technology.*
3:20 PM - 3:30 PM

We are conducting a sensitive high-contrast imaging survey that targets stars exhibiting long-term Doppler radial velocity trends. The goal of the program is to directly detect and characterize the object responsible for accelerating its host star. In this talk, I will present several recent discoveries and describe the unique science that can be accomplished when combining two powerful and complementary planet detection techniques.

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121 – Binaries and Interacting Systems

Oral Session – Room 3, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

121.01 – **Interacting Binary Star Research at the Kutztown University Observatory**

Phillip A. Reed[1]
[1]*Kutztown University.*
10:00 AM - 10:10 AM

The Kutztown University Observatory (KUO) is undergoing a transformation as is being used, once again, for quality photometric research. Built in 1968, KUO originally housed a 0.46-meter modified Cassegrain optical telescope, manufactured by Tinsley Laboratories and equipped with an EMI 6256 SA photomultiplier and a strip-chart recorder. This equipment produced professional results throughout the 1970s and 1980s. In 2010, KUO added a research-grade CCD camera (3072 x 2048, 9-micron pixels) and UBVRI filters for use with the Tinsley telescope.

Discussed here are several projects, ranging from the photoelectric work done in the 1970s to the new CCD light curves for the interacting Algol-type binaries Y Piscium, BO Monocerotis, and RW Geminorum. The latter works represent some of the first CCD investigations at KUO, but they also represent the last research using the aged Tinsley instrument. In 2012, KUO is replacing the original telescope with a new 0.61-meter Ritchey-Cretein optical telescope and is renewing and expanding its capabilities in photometric research.

121.02 – **The Discovered Exoplanets Have The Same Orbital Elements As Stellar Systems**

Helmut A. Abt[1]
[1]*Kitt Peak National Obs..*
10:10 AM - 10:20 AM

The Discovered Exoplanets Have the Same Orbital Elements as

Stellar Systems

Helmut A. Abt

Kitt Peak National Observatory, Tucson, AZ 85726; abt@noao.edu

There are two ways in which planetary masses are formed. One is in debris disks like that that produced the solar system. The other is as separate condensations in stars clusters. We now know that the luminosity function extends from stars through brown dwarfs to planetary masses. In the case of separate condensations, many planetary masses will be captured to become companions of stars. The exoplanet eccentricities are the same as those of stellar companions, and are six times larger than those of solar system planets. The exoplanet semi-major axes are like those of stellar companions and are six times smaller than solar system planets. We conclude that most of the exoplanets discovered to date were produced as separate condensations like stars and not in disks.

121.03 – **The Brown Dwarf Desert: A Tale of Stars Engulfing their Massive Close-in Companions**

Tristan Guillot[1], D. N. C. Lin[2], P. Morel[3]
[1]*OCA/UCSC, France,* [2]*UCSC,* [3]*OCA, France.*
10:20 AM - 10:30 AM

Although they are relatively frequent as free-floating objects, brown dwarfs are scarcely found as companions to solar-type stars. The paucity of brown dwarfs in close-orbits first noticed by radial velocity surveys has led to the concept of the "brown dwarf desert". We will show that this desert concerns in fact close companions with masses larger than about 3 Jupiter masses orbiting G-type stars. On the other hand, photometric surveys have shown that in fact F-type stars do possess close-in, massive companions. We will show that this is explained by the loss of an initial population of close-in massive giant planets and brown dwarfs due to tidal interactions: Because stars orbit less rapidly than their close-in companions, the tide raised on the star causes the companion to loose angular momentum and spiral in. The effect is much more pronounced around G-type stars because of a larger magnetic braking and because of increased dissipation, probably by internal gravity waves. We will use statistical methods to compare observations and model results and derive constraints on the tidal dissipation in stars as a function of their interior properties. This provides a powerful way to analyze the population of exoplanets and tie present observations with initial conditions at the time of the formation of these systems.

121.04D – **Eccentric Ellipsoidal Red Giant Binaries**

Christine Nicholls[1], P. Wood[2]
[1]*University of California San Diego,* [2]*Mt Stromlo Observatory, Australia.*
10:30 AM - 10:50 AM

Ellipsoidal variables are binaries in which the primary star is distorted by the influence of its small, close companion. By modelling ellipsoidal variables at known distances, it is possible to determine the exact masses of both components, despite the absence of eclipses.

We study a sample of red giant ellipsoidal variables, also known as sequence E stars, in the Large Magellanic Cloud. Roughly 10% of these ellipsoidal red giants have light curves with non-sinusoidal shapes, suggestive of eccentric orbits. We recently presented the first radial velocity curves confirming the eccentricity of these variables. Significant eccentricities in evolved binaries are not unknown, but remain unexplained by classical tidal theory.

Using both light and radial velocity curves of these eccentric ellipsoidal red giant binaries, we modelled the systems using the Wilson-Devinney code, to obtain the system parameters including exact masses. We also find evidence that the shape of the red giant changes throughout the orbit due to the high eccentricity and the varying influence of the companion. Defining the parameters of these systems paves the way for modelling to determine by what mechanism eccentricity is maintained in evolved binaries.

121.05 – **Intriguing Sources from the XMM-Newton Survey of Rich Open Clusters**

Natalie M. Gosnell[1], D. Pooley[2], A. M. Geller[3], R. D. Mathieu[1], J. Kalirai[4], P. Frinchaboy[5], E. Ramirez-Ruiz[6]

[1]University of Wisconsin-Madison, [2]Sam Houston State University, [3]Northwestern University, [4]Space Telescope Science Institute, [5]Texas Christian University, [6]University of California.

10:50 AM - 11:00 AM

We present results of our uniform survey of low-luminosity (<10^33 erg/s) X-ray sources in open clusters using XMM-Newton. Previous Chandra X-ray observations have shown a relationship between the number of X-ray sources in globular clusters and the cluster dynamical frequency. We investigate if a similar link exists in open clusters, utilizing X-ray, UV, and optical photometry and radial-velocity data. From 8 open clusters in our study we find a total of ~170 X-ray sources, with ~60-65 expected background sources. In our sample, 13 sources have luminosities above 2x10^31 erg/s. Six of the 13 have soft spectra, as shown through their X-ray color, and luminosities similar to quiescent LMXBs in globular clusters, including the previously detected quiescent LMXB candidate in NGC 6819. We also find 7 sources with hard spectra, whose X-ray colors and luminosities are similar to cataclysmic variables. We present the open cluster survey X-ray CMD, and discuss the possibility that the soft sources are quiescent LMXB candidates and may be a new class of X-ray objects to be found in open cluster environments. The presence of quiescent LMXBs in open clusters, if formed dynamically, may have important implications for understanding cluster dynamical environments.

This work is supported by National Science Foundation grant AST-0908082.

121.06 – **Modeling The Evolution Of Low Mass X-Ray Binaries In Globular Clusters**

Sanghamitra Goswami[1]

[1]Northwestern University.

11:00 AM - 11:10 AM

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.

121.07 – **Reflection Of X-rays In Oxygen Rich Disks Of Ultra-compact X-ray Binaries**

Oliwia Madej[1], P. G. Jonker[1], R. R. Ross[2]

[1]SRON, Netherlands, [2]Physics Department, College of the Holy Cross.

11:10 AM - 11:20 AM

Ultra-compact X-ray binaries (UCXB) are a subclass of low-mass X-ray binaries (LMXBs) with a very short orbital periods, typically less than 80 minutes. They consist of a neutron star or a black hole that accretes gas from a white dwarf. An important process observed in LMXBs is reflection. Photons emitted by the neutron star, jet nozzle or flares above the disc can be reflected off the accretion disc giving emission lines and free-free continuum emission. The most prominent reflection line is the Fe K α line at ~6.4 keV (assuming solar composition of the disc). If the infalling photons are reflected by the innermost part of the disc, effects such as gravitational redshift and the relativistic Doppler effect will broaden the reflection features in a characteristic way.

In the case of two UCXBs: 4U 0614+091 and 4U 1543-624 the donor star is most probably a carbon-oxygen white dwarf. Theory predicts that in the case in which the disc material is overabundant in oxygen, photons reflected off the disc will give a spectrum where the most prominent line is the O VIII Ly α line. A recently discovered broad emission feature at ~ 0.7 keV in XMM-Newton and Chandra observations of these two sources (Madej et al. 2010 in Press, Madej et al. 2011) was therefore interpreted as a relativistically broadened O VIII Ly α reflection line. This is the first time that a broad fluorescent O VIII Ly α line has been seen in an X-ray binary and it provides a new tool to probe extreme gravity.

I will present the observations showing the signatures of the reflection originating in the oxygen-rich discs and the results obtained using the new reflection model, which we adapted to the case of oxygen rich accretion disc.

121.08 – **Discovering The Quiet Stellar Mass Black Holes In The Milky Way**

Jifeng Liu[1]

[1]National Astronomical Observatory of China.

11:20 AM - 11:30 AM

Studies of stellar mass black holes are seriously limited by the small number of black holes known (two dozens versus ten millions expected) in the Milky Way, due to the limitation of the conventional way to discover black holes from X-ray outbursts. We have started an ambitious project to boost the stellar mass black hole sample from a new approach using UV signatures, made possible only recently by the availibility of all-sky GALEX UV survey, Sloan optical survey and the 5-year on-going LAMOST spectroscopic survey. Here I will present the preliminary analysis of the initial results, which show that we may obtain about 100-200 stellar mass black holes upon the completion of the project. I will also lay out the roadmap for the work needed to achieve the final goals.

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122 – Instrumentation: Ground, Air & Space

Oral Session – Summit Hall 3, Egan Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

122.01 – **Coronagraphic Imaging of Debris Disks from a High Altitude Balloon Platform**

Stephen C. Unwin[1], W. A. Traub[1], J. T. Trauger[1], G. Bryden[1], D. W. Stuchlik[2], C. F. Lillie[3]

[1]JPL, [2]NASA Wallops Flight Facility, [3]NGAS.

2:00 PM - 2:10 PM

Direct imaging of exoplanets orbiting nearby stars is a major observational challenge, demanding high angular resolution and extremely high dynamic range close to the parent star. Such a system could image and characterize the atmospheres of exoplanets, and also observe exozodiacal dust within the exoplanetary system. The ultimate experiment requires a space-based platform, but demonstrating much of the needed technology as well as performing valuable measurements of circumstellar debris disks, can be done from a high-altitude balloon platform.

In this paper, we show how progress in key technologies leads to a balloon experiment as a logical future step toward a space mission. The HCIT testbed has shown ultra-high contrast using small optics in a vacuum testbed. A recent ground-based experiment has demonstrated the ability to control three active optics in series - a lightweight controllable primary mirror, and two deformable mirrors - to achieve close to the best wavefront correction possible with large optics in an in-air testbed. We briefly describe the Wallops Arcsecond Pointer (WASP), which has had a very successful first flight, showing the capability of a balloon platform to stably point to the accuracy required for a coronagraph payload experiment. A balloon-borne coronagraph mission would incorporate all of these advances in an instrument that verifies each one in a space-like environment, and enabling forefront science. Such an experiment would be a step toward mitigating the technical risks of a major space-based exoplanet coronagraph.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

122.02 – **Advanced Technology Solar Telescope Construction: Progress Report**

Thomas R. Rimmele[1], J. McMullin[1], S. Keil[1], P. Goode[2], M. Knoelker[3], J. Kuhn[4], R. Rosner[5], ATST Team

[1]NSO, [2]NJIT, [3]HAO, [4]University Hawaii, [5]University Chicago.

2:10 PM - 2:20 PM

The 4m Advance Technology Solar Telescope (ATST) on Haleakala will be the most powerful solar telescope and the world's leading ground-based resource for studying solar magnetism that controls the solar wind, flares, coronal mass ejections and variability in the Sun's output. The ATST will provide high resolution and high sensitivity observations of the dynamic solar magnetic fields throughout the solar atmosphere, including the corona at infrared wavelengths. With its 4 m aperture, ATST will resolve magnetic features at their intrinsic scales. A high order adaptive optics system delivers a corrected beam to the initial set of five state-of-the-art, facility class instrumentation located in the coude laboratory facility. Photopheric and chromospheric magnetometry is part of the key mission of four of these instruments. Coronal magnetometry and spectroscopy will be performed by two of these instruments at infrared wavelengths. The ATST project has transitioned from design and development to its construction phase. Site construction is expected to begin in April 2012. The project has awarded design and fabrication contracts for major telescope subsystems. A robust instrument

program has been established and all instruments have passed preliminary design reviews or critical design reviews. A brief overview of the science goals and observational requirements of the ATST will be given, followed by a summary of the project status of the telescope and discussion of the approach to integrating instruments into the facility.

The National Science Foundation (NSF) through the National Solar Observatory (NSO) funds the ATST Project. The NSO is operated under a cooperative agreement between the Association of Universities for Research in Astronomy, Inc. (AURA) and NSF.

122.03 – **A Comparison Of The Flux Density Scales Between The Planck Mission And The VLA And ATCA Interferometers**

R. A. Perley[1], B. Butler[1], B. Partridge[2], P. Edwards[3], J. Stevens[3]

[1]National Radio Astronomy Observatory, [2]Haverford College, [3]Australia Telescope National Facility, Australia.

2:20 PM - 2:30 PM

The flux density scales at centimeter and millimeter wavelengths for ground-based telescopes is based, for frequencies higher than 5 GHz, on observations of the planets combined with emission models. The calibration of observations of the cosmic microwave background are now pinned to the known large-scale dipole patterns in the CMB induced by solar and Earth orbital velocity. The flux density scale for these experiments is then determined from observations of unresolved sources and the known pattern of the beam shape.

It is clearly of interest to compare results from these two independent scales. In December 2010, and again in January 2012, we set up observations with the VLA and the ATCA of a set of about 40 compact objects which were being observed simultaneously by Planck. Preliminary comparison of the scales with the data from the earlier experiment indicate excellent agreement. Here we report on the much larger and more complete data from the January 2012 observations.

122.04 – **Depth Dependent Background Measurements with the Nuclear Compton Telescope (NCT)**

Jeng-Lun Chiu[1], H. Chang[1], S. E. Boggs[2], NCT Collaboration

[1]Institute of Astronomy, National Tsing Hua University, Taiwan, [2]Space Sciences Laboratory, UC. Berkeley.

2:30 PM - 2:40 PM

The Nuclear Compton Telescope (NCT) is a balloon-borne soft gamma ray (0.2-10 MeV) telescope designed to study astrophysical sources of nuclear line emission and polarization. The heart of NCT is a compact array of 12 cross-strip germanium detectors (GeDs), providing high spectral resolution (~0.3-0.9% FWHM at 662 keV for most channels) and capability of tracking each photon interaction with full 3D position resolution to 2 mm^3. NCT has flown successfully on two conventional balloon flights to date, and the Crab Nebula was detected at a significance of 4σ in the second flight, which occurred on 2009 May 17 and 18 in Fort Sumner, New Mexico.

Here approximately 38 ks of background measurements in the second flight is studied from ground altitude to average float altitude (1.2-40 km). We discuss the expected contributions to the background component through detailed Monte Carlo simulations. Complete depth dependent environmental inputs are introduced, considering cosmic and atmospheric photon distributions, primary cosmic rays (protons), cosmic ray secondaries (protons and neutrons), and activation induced components. Imaging of the 511 keV annihilation line from the background is also attempted.

122.05 – **The Quality and Stability of Chandra Telescope Pointing and Spacial Resolution**

Ping Zhao[1]

[1]Harvard-Smithsonian, CfA.

2:50 PM - 3:00 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 spacial resolution. Chandra 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. I will review the issues of telescope pointing stability, optical Axis, aimpoint and their impacts to the Chandra operation, and evaluate the integrity and stability of the telescope. I will show images taken from all four detectors since launch to demonstrate the quality and stability of the Chandra spacial resolution.

122.06 – **Precision-Deployable, Stable, Optical Benches for Cost-Effective Space Telescopes**

Rolf Danner[1], S. Pellegrino[2], D. Dailey[1], G. Marks[1], J. Bookbinder[3]

[1]Northrop Grumman Corporation, [2]California Institute of Technology, [3]Smithsonia Astrophysical Observatory.

3:00 PM - 3:10 PM

To explore the universe at the arcsecond resolution of Chandra, while increasing collecting area by at least an order of magnitude and maintaining affordability, we will need to make creative use of existing and new technology. Precision-deployable, stable, optical benches that fit inside smaller, lower-cost launch vehicles are a prime example of a technology well within current reach that will yield breakthrough benefits for future astrophysics missions. Deployable optical benches for astrophysical applications have a reputation for complexity; however, we are offering an approach, based on techniques used in space for decades, that reduces overall mission cost.

Currently, deployable structures are implemented on JAXA's Astro-H and NASA's NuStar high-energy astrophysics missions. We believe it is now time to evolve these structures into precision, stable optical benches that are stiff, lightweight, and suitable for space telescopes with focal lengths of 20 meters or more. Such optical benches are required for advanced observatory class missions and can be scaled to Explorer and medium-class missions.

To this end, we have formed a partnership between Space Structures Laboratory (SSL) at the California Institute of Technology, Northrop Grumman Aerospace Systems (NGAS), Northrop Grumman Astro Aerospace (Astro), and Smithsonian Astrophysical Observatory (SAO). Combining the expertise and tools from academia and industry is the most effective approach to take this concept to Technology Readiness Level (TRL) 6. We plan to perform small sub-scale demonstrations, functional tests, and analytical modeling in the academic environment. Using results from SSL, larger prototypes will be developed at facilities at NGAS in Redondo Beach and Carpinteria, CA.

122.07 – **Design And Performance Of Micro-Spec, An Ultra Compact High-sensitivity Far-infrared Spectrometer For SPICA**

Giuseppe Cataldo[1], S. H. Moseley[2], W. Hsieh[2], W. Huang[2], T. R. Stevenson[2], E. J. Wollack[2]

[1]NASA GSFC (USRA), [2]NASA GSFC.

3:10 PM - 3:20 PM

Micro-Spec (μ-Spec) is a high-performance spectrometer working in the 250-700-μm wavelength range, whose modules use low-loss superconducting microstrip transmission lines on a single 4-inch-diameter silicon wafer. Creating the required phase delays in transmission lines rather than free space allows such an instrument to have, in principle, the performance of a meter-scale grating spectrometer. Such a dramatic size reduction enables classes of instruments for space that would be impossible with conventional technologies. This technology can dramatically enhance the long-wavelength capability of the space infrared telescope for cosmology and astrophysics SPICA. μ-Spec is analogous to a grating spectrometer. The phase retardation generated by the reflection from the grating grooves is instead produced by propagation through a transmission line. The power received by a broadband antenna is progressively divided by binary microstrip power dividers, and the required phase delays are generated by different lengths of microstrip transmission lines. By arranging these outputs along a circular focal surface, the analog of a Rowland spectrometer can be created. The procedure to optimize the Micro-Spec design is based on the stigmatization and minimization of the light path function in a two-dimensional bounded region, which results in an optimized geometry arrangement with three stigmatic points. In addition, in order to optimize the overall efficiency of the instrument, the emitters are directed to the center of the focal surface. The electric field amplitude and phase as well as the power transmitted and absorbed throughout the region are analyzed. Measurements are planned in late summer to validate the designs. This material is based upon work supported by NASA through the ROSES/APRA program. This research was supported by an appointment (Cataldo) at the Goddard Space Flight Center administered by Universities Space Research Association through a contract with NASA.

122.08 – **The HST Object Catalog**

Stephen H. Lubow[1], T. Budavari[2]

[1]Space Telescope Science Institute, [2]Johns Hopkins University.

3:20 PM - 3:30 PM

We have created a catalog of objects observed by the WFPC2 and ACS instruments on the Hubble Space Telescope (HST). The catalog is based on observations taken on more than 6000 visits (telescope pointings) of ACS/WFC and more than 25000 visits of WFPC2. The catalog is obtained by cross-matching all Hubble Legacy Archive (HLA) Source Extractor source lists for these instruments. The source lists describe source detections within a visit. As a biproduct of the cross-matching, we obtain improved relative astrometry of the HST images. We apply a Bayesian method to help determine which source detections likely match. The catalog provides information about which source detections match together across visits. For each source detection, the catalog contains information that includes the corrected position, the name of the image, the filter, the exposure time, the exposure start and stop times, and the source magnitude. We also provide information on nondetections that can be used to determine dropouts. The catalog will be made publicly available.

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123 – Solar Magnetism & the Activity Cycle II

Oral Session – Room 5, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

123.01 – **On the Maintenance of Meridional Circulation and Differential Rotation in the Sun**

Nicholas Featherstone[1], M. S. Miesch[1]

[1]High Altitude Observatory.

2:00 PM - 2:15 PM

We examine the interaction of meridional circulations and differential rotation driven by convective motion in the Sun. Using 3-dimensional hydrodynamic

simulations carried out with the ASH code, we present a class of solar convection models that demonstrate the existence of two distinct regimes of meridional circulation. These two regimes depend predominantly on the the vigor of the convective driving and posses, in one instance, a single monolithic cell of circulation in each hemisphere, and in the other instance, a single cell at high latitudes

with multiple cells at low latitudes. We explore the long-term evolution of these two regimes and demonstrate that the action of a single cell is to speed up the poles relative to the equator. The compatibility of such a circulation with a solar-like differential rotation profile then relies somewhat delicately on the ability of convective Reynolds stresses to balance these effects, or on the ability of convection to establish sufficiently strong latitudinal entropy gradients (warm pole, cool equator) which work to suppress the strength of this cell. Such gradients are already suspected of existing in the subadiabatic layers beneath the convection zone owing to their ability to facilitate radial differential rotation contours. We thus explore the effects of the inclusion of an overshooting region in our simulations, and find that such a layer also promotes the maintenance of a fast equator.

123.02 – **Latest Results on the Torsional Oscillation and Solar Cycle 25**

Frank Hill[1], R. Howe[2], J. Schou[3], M. Thompson[4], T. Larson[3], R. Komm[1]

[1]*National Solar Obs.,* [2]*University of Birmingham, United Kingdom,* [3]*Stanford University,* [4]*High Altitude Observatory.*

2:15 PM - 2:30 PM

The Torsional Oscillation in the Sun is a zonal (East-West) flow that is slightly faster than the background differential rotation profile. The location of this flow slowly migrates in latitude over a period of several years. There are two branches of the flow: an equatorward branch that underlies the active regions, and a poleward branch. The timing of the equatorward migration is correlated with the timing of the solar cycle such that the activity for a cycle appears when the center of the flow reaches latitude 25 degrees. In addition, the poleward branch appears about 12 years prior to the activity for a cycle. Thus we should have observed the onset of Cycle 25 in 2008, but did not. This poster will update the observations to 2012, and present a new analysis that shows that the Cycle 25 flow appeared in 2010, but was hidden by a change in the background differential rotation profile. These results suggest that the next minimum will be two years longer than average, and that Cycle 25 will begin in 2022.

123.03 – **Cycle 24 Northern-Hemisphere Solar Maximum Observed in Fe XIV**

Richard C. Altrock[1]

[1]*Air Force Research Lab..*

2:30 PM - 2:45 PM

The onset of the "Rush to the Poles" of polar crown prominences and their associated coronal emission is a harbinger of solar maximum. Altrock (2003, Solar Phys. 216, 343) showed that the "Rush" was well-observed in the the Fe XIV corona at the Sacramento Peak site of the National Solar Observatory prior to the maxima of Cycles 21 to 23. He found that solar maximum in those cycles occurred when the center line of the Rush reached a critical latitude. These latitudes were 76°, 74° and 78°, respectively, for an average of 76° ± 2°.

Applying this method to Cycle 24 is difficult due to the unusual nature of this cycle. Cycle 24 displays an intermittent "Rush" that is only definable in the northern hemisphere. In 2009 an initial slope of 4.6°/yr was found, compared to an average of 9.4 ± 1.7 °/yr in the previous cycles. However, in 2010 the slope increased to 7.5°/yr (an increase did not occur in the previous three cycles). Extending that rate to 76° ± 2° indicates that the maximum smoothed sunspot number in the northern hemisphere ALREADY OCCURRED at 2011.6 ± 0.3. Unfortunately, the smoothed sunspot number uses 12-month running means, so the result may not be testable for several more months. Solar maximum may not be detectable in the southern hemisphere.

123.04 – **Calibration Of a Century of Polar Field Measurements and what this Tells us About the Long-term Variability of the Solar and Heliospheric Magnetic Field**

Andres Munoz-Jaramillo[1], N. R. Sheeley[2], J. Zhang[3], E. E. DeLuca[1]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Naval Research Laboratory,* [3]*George Mason University.*

2:45 PM - 3:00 PM

In addition to the well known 11-year periodicity, the solar cycle also presents long-term modulations of its amplitude and period which play a determinant role in the evolution of space weather and climate. To this date, the efforts at understanding long-term solar variability have focused on the active parts of the cycle using sunspot properties as their main source of data. However, the recent extend minimum of sunspot cycle 23 has shown us that the quiet parts of the cycle are equally important and thus long-term databases complementary to sunspot properties are necessary.

Here we show how to consolidate Mount Wilson Observatory polar faculae data from four observational campaigns (1906-1964, Sheeley 1966; 1960-1975, Sheeley 1976; 1975-1990, Sheeley 1991; 1985-2007, Sheeley 2008), validate it through a comparison with facular data counted automatically from MDI intensitygrams, and calibrate it against polar field measurements taken by the Wilcox Solar Observatory (1977-2011) and average polar field and total polar flux calculated using MDI line-of-sight magnetograms (1996-2011).

We also show that the consolidated polar facular measurements are in excellent agreement with both polar field and polar flux estimates, making them an ideal proxy to study the evolution of the polar magnetic field since 1906 and use this proxy to study the role of polar flux in the evolution of the solar cycle and the Heliospheric Magnetic Field (HMF).

123.05 – **Active Longitudes Revealed by Large-scale, and Long-lived Coronal Streamers**

Jing Li[1]

[1]*ESS, UCLA.*

3:00 PM - 3:15 PM

While well established on other stars, the existence of active longitudes on the sun has been a controversial subject for several decades. Using the clearly observed large-scale, long-lived coronal streamers, we are able to provide fresh evidence concerning the existence of active longitudes. These large-scale coronal streamers are easily seen on full limb synoptic maps. In this presentation, we will show that the large-scale, long-lived coronal streamers are physically connected with the more equatorial active regions. By tracing these streamers over a 5 year period (2006-2010), we found the underlying sunspot groups to occupy two longitudinal bands about 100 deg. wide and 180 deg. apart. The study provides observational evidence that the emerging magnetic field is not uniform in azimuth, as distinct from the azimuthal symmetry assumed in many models.

123.06 – **Spies - Spectral Polarimetric Imager For The Energetic Sun**

Haosheng Lin[1], S. Jaeggli[2]

[1]*Univ. of Hawaii,* [2]*Montana State University.*

3:15 PM - 3:30 PM

Spectropolarimetric observation with uncompromised spatial, spectral, and temporal resolution simulatneously over a substantial 2D field and multiple spectral lines is the key to the resolution of many important questions in modern solar physics. While 2D imaging spectroscopy based on fiber optics integral field unit and image slicer has a long history nighttime astronomy, adaptation for solar observation occured only recently. This paper will present preliminary results of magnetic field observation in the HeI 1083 nm and FeI 1565 nm lines obtained with SPIES --- a true imaging spectropolarimeter based on a large format (64 x 32 fibers input array) fiber-optic array optimized for the study of evolution of magnetic and thermodynamic properties of energetic and dynamic phenomena of the sun. We will also discuss considerations for the use of fiber-optic array for solar spectropolarimetric applications, as well as the design of SPIES.

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124 – Chromosphere & Transition Region

Oral Session – Room 4, Dena'ina Center – 6/11/2012 2:00:00 PM to 6/11/2012 3:30:00 PM

124.01 – **Simultaneous Imaging and Spectroscopy by Inversion of MOSES Sounding Rocket Data**

Charles Kankelborg[1], S. Atwood[1], H. Courrier[1], J. Plovanic[1], T. Rust[1]

[1]*Montana State Univ..*

2:00 PM - 2:15 PM

The Multi-Order Solar EUV Spectrograph (MOSES) forms 304 Å EUV images at three spectral orders from an objective multilayer grating. The images encode spatial and spectral data over a 20 x 10 arc minute field of view. We describe an inversion algorithm and present spectra derived thereby from data obtained during the 2006 flight.

We gratefully acknowledge the support of the NASA Heliophysics LCAS program.

124.03 – **Evidence for Two Separate But Interlaced Components of the Chromospheric Magnetic Field**

Karin Muglach[1], K. Reardon[2], Y. Wang[3], H. Warren[3]

[1]*GSFC,* [2]*Osservatorio Astrofisico di Arcetri, Italy,* [3]*Naval Research Laboratory.*

2:30 PM - 2:45 PM

Chromospheric fibrils are generally thought to trace out horizontal magnetic fields that fan out from flux concentrations in the photosphere. A high-resolution (0.2") image taken in the core of the Ca II 854.2 nm line shows the dark fibrils within an active region remnant as fine, looplike features that are aligned parallel to each other and have lengths on the order of a supergranular diameter (~30 Mm). Comparison with a line-of-sight magnetogram confirms that the fibrils are centered above intranetwork areas, with one end rooted just inside

the neighboring plage or strong unipolar network but the other endpoint less clearly defined. Focusing on a particular arcade-like structure lying entirely on one side of a filament channel (large-scale polarity inversion), we find that the total amount of positive-polarity flux underlying this ``fibril arcade'' is 50 times greater than the total amount of negative-polarity flux. Thus, if the fibrils represent closed loops, they must consist of very weak fields (in terms of flux density), which are interpenetrated by a more vertical field that contains most of the flux. This surprising result suggests that the fibrils in unipolar regions connect the network to the nearby intranetwork flux, while the bulk of the network flux is diverted upward into the corona and connects to remote regions of the opposite polarity. We conclude that the chromospheric field near the edge of the network has an interlaced structure resembling that in sunspot penumbrae, with the fibrils representing the low-lying horizontal flux that remains trapped within the highly nonpotential chromospheric layer.

124.04 – **Modeling Of Magnetic Fields In The Solar Chromosphere: Flux Emergence And Magnetic Reconnection**

James E. Leake[1], M. G. Linton[2], V. Lukin[2]

[1]George Mason University, [2]Naval Resrach Laboratory.

2:45 PM - 3:00 PM

The solar chromosphere is the complex, dynamic, inhomogeneous layer which links the photosphere and corona above. The low ionization around the temperature minimum, non-thermodynamic heating mechanisms, and complicated radiative transfer combine to make this a difficult region to include in numerical models of active regions. In the low-beta regions of the chromosphere, the main effect of the chromospheric conditions on the dynamics of magnetic fields is the anisotropy in the generalized Ohm's law caused by the presence of neutral Hydrogen. This anisotropy results in currents perpendicular to the field being dissipated orders of magnitude faster than currents parallel to the field (this is sometimes known as ambipolar diffusion, or Cowling/Pedersen dissipation). We present results from both single-fluid and two-fluid (plasma+neutral gas) simulations which include this effect. We first look at simple reconnection geometries, and show how decoupling of plasma and neutrals can lead to fast reconnection. Then, in results from single fluid simulations, we show how Cowling dissipation acts as a filter to emerging magnetic fields, affecting both the dynamics of active regions, and the onset of reconnection that occurs during active region formation.

124.05 – **Convection-Chromosphere Coupling due to Vortex Tube Dynamic**

Irina Kitiashvili[1], A. Kosovichev[1], N. Mansour[2], A. Wray[2]

[1]Stanford University, [2]NASA Ames Research Center.

3:00 PM - 3:15 PM

Ubiquitous distribution of small-scale vortex tubes on the solar surface was found both in observations and simulations. Complicated dynamics of the turbulent vortex tubes is a source of various observed effects such as acoustic waves excitation and processes of self-organization in magnetized solar plasma. We use realistic-type radiative 3D MHD simulations to investigate in detail different mechanisms of the vortex tube formation by granular flows in the upper convection zone, appearance of vortex tubes on the surface and their interaction with the atmosphere. The simulation results reveal new interesting effects of penetration of the vortex tubes from the turbulent subphotosphere into the chromosphere, interaction between these layers, and influence of the helical motions on thermodynamic properties of the chromosphere. In the presence of background magnetic field, the vortex tubes lead to formation of compact magnetic flux tubes, playing important role in the mass and energy flux into the chromosphere. We discuss implication of the simulation results for future high-resolution observations.

124.06 – **An Insight Into Atmospheric Structure Through Compact Chromospheric Brightenings**

Michael S. Kirk[1], K. Balasubramaniam[2], J. Jackiewicz[1], R. McAteer[1]

[1]New Mexico State University, [2]Air Force Research Laboratory.

3:15 PM - 3:30 PM

Compact chromospheric brightenings have a range of intensities, Doppler velocities, and magnetic field strength each giving clues to their physical origin. One type of compact brightening, sequential chromospheric brightening (SCB), has several properties of small-scale chromospheric evaporation. SCBs appear adjacent to two ribbon flares with associated halo CMEs. This work presents a definition of SCBs constrained by a statistical analysis of several chromospheric flaring events. From this definition of SCBs, we extract physical qualities of SCBs and correlate these qualities with data gathered from additional layers of the solar atmosphere. Using these dynamic measurements, we suggest a connection between compact brightenings, the erupting flare, and overarching magnetic loops.

125 – Is the Magnetosphere of Jupiter a Colossal Comet? What will NASA's Juno Reveal?

Invited Session – Ballroom B, Dena'ina Center – 6/11/2012 3:40:00 PM to 6/11/2012 4:30:00 PM

125.01 – **Is the Magnetosphere of Jupiter a Colossal Comet? What will NASA's Juno Reveal?**

Fran Bagenal[1]

[1]Univ. of Colorado.

3:40 PM - 4:30 PM

Not surprisingly, the king of the planets has the strongest magnetic field among the planets of our solar system, with a reach extending far beyond its orbiting moons. The volcanic moon Io loses a ton of atmospheric material every second, gas that becomes ionized and swept up by the magnetic field. Iogenic plasma fills Jupiter’s giant magnetosphere. Jupiter’s magnetosphere is the largest structure in the solar system, averaging about 150 times the width of the planet. The solar wind streams past Jupiter, stretching the planet’s magnetosphere into a long tail that can reach past the orbit of Saturn. The iogenic plasma is ultimately ejected down the tail and lost to the solar wind. Juno’s orbit over Jupiter’s poles is designed to allow the spacecraft to map Jupiter’s gravity and magnetic fields and the amount of water in its atmosphere, but the polar vantage point also affords Juno a perfect opportunity to study this completely unexplored region of magnetosphere. Some of the charged particles in the magnetosphere are funneled into the polar atmosphere to create intense auroral emissions, which Juno will observe with unprecedented resolution. Juno's stretched out orbit around Jupiter will also enable it to sample different portions of the magnetosphere over the course of the mission, building a more complete picture of the auroras and processes that control them. Instruments on the spacecraft will measure the flux particles that interact with the atmosphere to generate the auroras. Ultraviolet and infrared images will provide visual context for data from the magnetometer, plasma and radio-wave instruments, which will elucidate how charged particles are accelerated to 10s of keV energies in Jupiter's magnetosphere.

126 – Exploring the Planet Mercury: One Year of MESSENGER Orbital Observations

Invited Session – Ballroom B, Dena'ina Center – 6/11/2012 4:30:00 PM to 6/11/2012 5:20:00 PM

126.01 – **Exploring the Planet Mercury: One Year of MESSENGER Orbital Observations**

Sean C. Solomon[1]

[1]Carnegie Inst. of Washington.

4:30 PM - 5:20 PM

Launched in 2004, MESSENGER flew by Mercury three times in 2008-2009 en route to becoming the first spacecraft to orbit the solar system’s innermost planet in March 2011. MESSENGER’s chemical remote sensing measurements of Mercury’s surface indicate that the planet’s bulk silicate fraction, low in Fe and high in Mg, differs from those of the other inner planets. Moreover, surface materials are richer in the moderately volatile constituents S and K than predicted by most current models for inner planet formation. Global image mosaics and targeted high-resolution images reveal that Mercury experienced globally extensive volcanism, including large expanses of plains emplaced as flood lavas and widespread examples of pyroclastic deposits likely emplaced during explosive eruptions of volatile-bearing magmas. Bright deposits within impact craters host fresh-appearing, rimless depressions or hollows, often with high-reflectance interiors and halos and likely formed through processes involving the geologically recent loss of volatiles. The large-scale deformational history of Mercury, although dominated by near-global contractional deformation as first seen by Mariner 10, is more complex than first appreciated, with numerous examples of extensional deformation that accompanied impact crater and basin modification. Mercury’s magnetic field is dominantly dipolar, but the field is axially symmetric and equatorially asymmetric, a geometry that poses challenges to dynamo models for field generation. The interaction between the solar wind and Mercury’s magnetosphere, among the most dynamic in the solar system, serves both to replenish the exosphere and space weather the planet’s surface. Plasma ions of planetary origin are seen throughout the sampled volume of Mercury’s magnetosphere, with maxima in heavy-ion fluxes in the planet’s magnetic-cusp regions. Bursts of energetic electrons, seen at most local times, point to an efficient acceleration mechanism operating within Mercury’s magnetosphere on a regular basis that produces electrons with energies up to hundreds of keV on timescales of seconds.

127 – Transits of Venus and Mercury: Exoplanet Analogs in Our Solar System

Invited Session – Ballroom B, Dena'ina Center – 6/11/2012 8:00:00 PM to 6/11/2012 9:00:00 PM

127.01 – **Transits of Venus and Mercury: Exoplanet Analogs in Our Solar System**

Jay M. Pasachoff[1]

[1]Williams College.

8:00 PM - 9:00 PM

Since Johannes Kepler's predictions of transits of Mercury and Venus in 1631, and observations by Jeremiah Horrocks and William Crabtree of the 1639 transit of Venus, only 5 other transits of Venus have been observed: in 1761 and 1769, 1874 and 1882, and 2004. Expeditions were sent all over the world for the 18th and 19th century transits to follow the methods of Halley and others to determine the Astronomical Unit, giving the size and scale of the solar system, arguably the most important problem in astronomy for centuries. I will discuss how the infamous black-drop effect bedeviled astronomers in that quest for an accurate A.U., and how Glenn Schneider and I explained the effect through satellite observations of transits of Mercury, showing that it was not simply caused by the Cytherean atmosphere. During the 2004 transit, we worked with Richard Willson of ACRIMsat to detect the 0.1% drop in the Total Solar Irradiance, showing the effect of solar limb darkening, positioning such observations of transits of Venus and of Mercury as analogs to exoplanet transits. Our observations of the atmosphere of Venus with NASA's Transition Region and Coronal Explorer in 2004 led us to plan extensive observations of Venus's atmosphere and other phenomena during the June 5, 2012, transit of Venus, the last to be visible from Earth until 2117. We will have used NASA's Solar Dynamics Observatory, Hinode, ACRIMsat, and other spacecraft, and ground-based solar telescopes at Sacramento Peak, Kitt Peak, Big Bear, and Haleakala to observe the transit; I hope to give preliminary reports on these observations during this talk. Further, I will discuss the plans of Ehrenreich and colleagues for Hubble observations of this transit and our hopes of detecting transits of Venus and Earth as seen from Jupiter and Saturn over the next few years.

128 – Solar System

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

128.01 – **On The Distribution Of Angular Orbital Elements Of Near-earth Objects**

Youngmin JeongAhn[1], R. Malhotra[1]

[1]*Lunar and Planetary Laboratory, University of Arizona.*

9:00 AM - 6:30 PM

The longitude of ascending node Ω and the argument of periapsis ω are expected to be randomly distributed for near-Earth objects (NEOs). However, the distribution of these angles for the Apollo, Amor and Aten subclasses, considered separately, shows some striking non-random features. We explain how these features arise due to observational biases. The distribution of Ω has maxima near 0 and 180° and is affected by observational difficulty due to the galactic plane at the opposition and other seasonal effects. The ω distributions of Aten and Amor subclasses have minima at 90° and 270° while Apollos have minima at 0 and 180°. This is explained by the greater detectability of NEOs at close approach to Earth. The longitude of perihelion Ω+ω also has a strongly non-random distribution that may be owed to actual dynamical effects. Understanding the distribution of unobserved NEOs will help to improve planning for the next generation of NEO surveys. A better understanding of the intrinsic distribution of NEOs is important for estimating the impact hazard at Earth; it is also important for understanding the impact history of the Moon and the terrestrial planets.

128.02 – **The Shape and Spin Distributions of Near-Earth Asteroids Observed with the Arecibo Radar System**

Patrick A. Taylor[1], E. S. Howell[1], M. C. Nolan[1], A. A. Thane[2]

[1]*Arecibo Observatory,* [2]*The University of Montana.*

9:00 AM - 6:30 PM

Radar observations of near-Earth asteroids have revealed a heterogeneous population with diameters spanning meter to kilometer scales, diverse shapes ranging from simple spheroids to extremely irregular bodies, and rotation periods stretching from minutes to weeks. Since 1998, when the Arecibo Observatory S-band radar system was upgraded to transmit up to 1 MW, over 300 near-Earth asteroids have been observed. Thane et al. (2012; AAS 219, #432.14) examined those asteroids observed through 2010 that were well resolved at high power (above 600 kW output) and observed on multiple days allowing for unambiguous basic shape determination and found that the population was rather evenly distributed among spheroids, elongated bars, double-lobed contact binaries, multiple-asteroid systems, and irregularly shaped asteroids. This seems to imply that there is no dominant process of near-Earth asteroid evolution funneling the population to a general shape. Furthermore, there was no clear correlation between size and shape. We will expand the Thane et al. shape distribution to include objects observed from 2011-2012. We will also determine the spin distribution of radar-observed near-Earth asteroids, using the echo bandwidths to place upper limits on the spin periods of the bodies (allowing for comparisons to lightcurve-derived periods where available) and examine possible correlations between sizes, shapes, and spins.

128.03 – **A Multiwavelength Investigation of the Remains of Sungrazing Comet Lovejoy (C/2011 W3)**

Matthew M. Knight[1], H. A. Weaver[2], Y. R. Fernandez[3], S. R. Chesley[4], M. S. Kelley[5], R. McNaught[6], D. Bodewits[5], C. M. Lisse[2], D. J. Osip[7], N. Dello Russo[2], K. Battams[8]

[1]*Lowell Observatory/JHU-APL,* [2]*Johns Hopkins University Applied Physics Laboratory,* [3]*University of Central Florida,* [4]*California Institute of Technology, Jet Propulsion Laboratory,* [5]*University of Maryland,* [6]*Siding Spring Observatory, Australian National University, Australia,* [7]*Las Campanas Observatory, Carnegie Observatories, Chile,* [8]*Naval Research Laboratory.*

9:00 AM - 6:30 PM

Comet Lovejoy (C/2011 W3) was the first Kreutz sungrazing comet in the modern telescopic era (since 1970) to survive perihelion, although the extent to which the nucleus survived is unclear. We used observations by SOHO and STEREO obtained near perihelion as well as observations we acquired with the Hubble Space Telescope, Spitzer Space Telescope, Swift, Siding Spring Observatory, Las Campanas Observatory, and Lowell Observatory in the days and weeks after perihelion (2011 December 16) to constrain the size of any remaining nucleus and study the effects of the intense solar radiation near perihelion (q~1.2 solar radii) on the comet. Preliminary analysis suggests that no substantial nucleus survived for more than a few days after perihelion. However, significant quantities of dust were produced and were still visible in Spitzer data acquired in early 2012 February. Analysis of the data is ongoing and new results will be reported.

Acknowledgements: Support for SOHO and STEREO data analysis was provided by NASA Planetary Mission Data Analysis Program grant NNX10AP75G. Telescope time was granted under HST program DD 12792, Spitzer program 80237, and Swift target ID 32251.

128.04 – **The Fate Of The Solar System Around A Dying Sun: White Dwarfs And Dark Planets**

Ciprian T. Berghea[1], V. V. Makarov[1], R. P. Dudik[1], P. P. Eggleton[2]

[1]*USNO,* [2]*LLNL.*

9:00 AM - 6:30 PM

What is the fate of planetary systems when the star goes

through the red giant phase and eventually becomes a white dwarf? Do we expect to detect planets around white dwarfs? Are the planets ejected when perturbed by the high mass-loss episodes? This study aims at answering all of these questions using our own Solar system as a case study. The interior planets are either directly engulfed by the Sun in the red-giant phase or - for Mars - the tidal forces cause the planet to fall on the swollen Sun. Using an adapted version of the code Mercury, we integrated the remaining four exterior planets to the white dwarf phase of the Sun, running hundreds of simulations with different initial conditions. Our results show that it is very likely that some of the planets will be ejected during the red giant phase and others will survive. The fate of these planets depend on their orbits and their mass.

129 – Extrasolar Planets

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

129.01 – **Detecting The Magnetic Field Of The Transiting Exoplanet Wasp-12b Through Ground-based And Space-based Near-UV And Optical Observations**

Jake Turner[1], C. A. Griffith[1], J. K. Teske[1], B. E. Crawford[1], A. N. Robertson[1], B. M. Smart[1], K. K. Hardegree-Ullman[1], R. T. Zellem[1]

[1]*University of Arizona.*

9:00 AM - 6:30 PM

We observed four primary transits of the transiting exoplanet WASP-12b with the Steward Observatory 1.55 meter Kuiper Telescope using near-UV and optical filters and with the UVW1 near-UV filter on NASA's Swift satellite. It has been proposed that you can detect the magnetic field of a transiting exoplanet by observing asymmetries in their near-UV and optical light curves (Vidotto et al. 2011) and we hope to observe this phenomenon. Preliminary analysis of our ground-based data shows no asymmetry between near-UV and optical wavelengths. Future analysis of our complete set of data should help provide some of the first constraints on whether this effect proposed by Vidotto et al. 2011 can be observed from the ground and whether it is dependent on certain wavelengths.

129.02 – **Characterization of Exoplanets in Eccentric Orbits**

Stephen R. Kane[1], D. M. Gelino[1]

[1]*NASA Exoplanet Science Institute, Caltech.*

9:00 AM - 6:30 PM

Planets in eccentric orbits comprise a significant fraction of the total number of detected exoplanets, particularly giant planets. Understanding their orbits is a key component in the study of formation and stability scenarios which can explain the current eccentricity distribution. We show how refinement of the orbits can be used to explore this domain and further show how characterization can be achieved through observations near periastron passage. We further describe how these observations can be used as a diagnostic to distinguish between high-mass planets and low-mass stars.

129.03 – **The Habitable Zone Gallery and its Applications**

Dawn M. Gelino[1], S. R. Kane[1]

[1]*NASA Exoplanet Science Institute, Caltech.*

9:00 AM - 6:30 PM

The Habitable Zone Gallery (www.hzgallery.org) is a 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, a plot with the period and eccentricity of each of the planets with respect to their time spent in the HZ, a gallery of known systems which plot the orbits and the location of the HZ with respect to those orbits, and orbital movies. Here we discuss various educational and scientific applications of the site such as target selection, exploring planets with eccentric orbits, and investigating habitability.

129.04 – **Near-UV and Optical Observations of the Transiting Extrasolar Planet Tres-3b**

Carter-Thaxton W. Smith[1], B. Smart[1], J. D. Turner[1], A. Walker-LaFollette[1], K. K. Hardegree-Ullman[1], L. C. Small[1], A. M. McGraw[1], B. E. Crawford[1], T. M. Carleton[1], A. N. Robertson[1], A. P. M. Towner[1], M. J. Daugherty[1], B. Guvenen[1]

[1]*University of Arizona.*

9:00 AM - 6:30 PM

Recent observations of transiting extrasolar planets in near-UV and optical bands, by Vidotto et al. 2011, suggest that asymmetries in light curve ingress times indicate the presence of a magnetic field. The University of Arizona Astronomy Club observed primary transits of extrasolar planet TrES-3b using the 1.55m Kuiper Telescope in the U, B, V, and R photometric bands in order to detect this phenomenon. We have reanalyzed transit data collected between 2009 and 2012 in order to have a consistent reduction methodology and eliminate any systematic errors. Using the Transit Analysis Package (TAP) and the JKTEBOP transit modeling code, we have modeled all of our transits to detect any light curve asymmetries between near-UV and optical bands.

129.05 – **A Transiting Brown Dwarf Candidate from the KELT-North Transit Survey**

Robert Siverd[1]

[1]*Vanderbilt University.*

9:00 AM - 6:30 PM

I present and discuss a promising transiting brown candidate identified by the KELT-North survey. KELT-North (Kilodegree Extremely Little Telescope-North) is a small-aperture (42mm), wide-field (26 x 26 degree) robotic survey system designed to detect high-value transiting exoplanet systems around bright (8 < V < 10) stars. The KELT-North survey has been operating since 2006 and pans 40% of the Northern sky. Brown dwarfs occupy a sparsely-populated region of parameter space between planets and stars. Transiting brown dwarfs provide a rare and unique opportunity to refine our knowledge of this relatively unknown object class. We briefly discuss the implications of such systems for existing models of planet formation and migration.

129.06 – **Realistic Simulations of the Planetary Yields of KMTNet, a Next-Generation Microlensing Survey**

Calen B. Henderson[1], B. S. Gaudi[1]

[1]*The Ohio State University.*

9:00 AM - 6:30 PM

Gravitational microlensing is complementary to other exoplanet search techniques, particularly in its ability to detect low-mass planets at large distances from their host stars. As a result, microlensing provides an integral component to any statistical investigation of the demographics of exoplanet populations. The observational methodology of this technique is poised to enter the next generation, as survey telescopes with large apertures and wide fields of view come online in the next several years. Here we present predictions for the planetary detection yields from the Korean Microlensing Telescope Network (KMTNet), which is just such a next-generation network. KMTNet consists of three telescopes to be located in Chile, South Africa, and Australia. Together these telescopes will provide complete longitudinal coverage and so nearly continuous observations of the southern sky after coming fully online in 2014. With 1.6m apertures, 4 square degrees fields of view, and high cadences, KMTNet will be the first survey network to detect and characterize planets without needing additional follow-up resources. Here we present a Monte Carlo simulation that predicts the ability of KMTNet to detect planets at a range of planet masses and planet-star separations, accounting for real-world effects such as weather, the atmosphere, the moon, and realistic observational uncertainties. We improve upon previous simulations by including high-magnification events and more realistic error estimates. Finally, we examine the impacts of various trade-offs, including number of fields vs. cadence, on the overall detection rate, and use these to propose an optimal observational strategy.

C.B.H. acknowledges the support of the NSF Graduate Research Fellowship 2011082275.

129.07 – **Time-resolved Ultraviolet Spectroscopy of the GJ 876 Exoplanetary System**

Kevin France[1], F. Tian[1], J. L. Linsky[1], C. S. Froning[1], A. Roberge[2], J. T. Stocke[1]

[1]*University of Colorado,* [2]*GSFC.*

9:00 AM - 6:30 PM

Extrasolar planets orbiting M-stars may represent our best chance to discover habitable worlds in the coming decade. The ultraviolet spectrum incident upon both Earth-like and Jovian planets is critically important for proper modeling of their atmospheric heating and chemistry. In order to provide a more realistic input for atmospheric models of planets orbiting low-mass stars, we present new near- and far-ultraviolet spectroscopy of the M-dwarf exoplanet host GJ 876 (M4V). Using the COS and STIS spectrographs aboard the Hubble Space Telescope, we have characterized the 1150-3140A spectrum of GJ 876. We have reconstructed the stellar HI LyA emission line profile, and find that the integrated LyA flux is roughly twice the rest of the integrated flux in the 1150-3140A ultraviolet bandpass (F(LyA)/F(FUV+NUV) ~ 2). This LyA/(FUV+NUV) ratio is approximately four orders of magnitude greater than the solar value. We present a description of the ultraviolet line spectrum and report surprisingly strong fluorescent emission from hot H2 (T > 2000 K). We describe the light-curve of a chromospheric + transition region flare observed in several far-UV emission lines, with flare/quiescent ratios >~10. The strong far-ultraviolet radiation field of an M-star (and specifically LyA) may be important for determining the abundance of O2 in the lower atmosphere, and the formation of biomarkers, for Earth-like planets in the habitable zones of low-mass stars.

130 – Massive Stars, Stellar Atmospheres, and Stellar Winds

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

130.01 – **LMC O Supergiant Mass Loss Rates Determined from P V, S V and IR Excesses**

Derck Massa[1], R. Prinja[2], A. Fullerton[1], D. Lennon[1]

[1]*STScI,* [2]*UCL, United Kingdom.*

9:00 AM - 6:30 PM

We use HST/STIS and FUSE spectra and Spitzer/IRAC photometry to obtain independent mass loss rates for 7 LMC O supergiants. The mass loss rates are derived from the P Cygni profiles of the P V 1118, 1128 resonance doublet, the S V 1502 and N IV 1718 excited state lines, and the IR excesses of a combination of ground based and Spitzer photometry. The different mass loss rates are compared to each other and to theoretical expectations. We discuss the causes for the differences between the various determinations.

130.02 – **Limb-darkening Coefficients For GK Dwarf Stars From The SAtlas Stellar Atmospheres Code**

Hilding R. Neilson[1]

[1]*University of Bonn, Germany.*

9:00 AM - 6:30 PM

Hundreds of extrasolar planets have been detected from transit observations, which also measure the intensity profile of host stars in the form of a limb-darkening law. These observations of stellar limb darkening help constrain the properties of the planet, however, in some cases, measured limb-darkening coefficients disagree with limb-darkening coefficients computed from plane-parallel model stellar atmospheres. Currently, these differences cannot be explained for all cases. In this work, I compute limb-darkening coefficients from plane-parallel and spherically-symmetric model stellar atmospheres to understand the role of model geometry in constraining limb-darkening coefficients. We compare model limb-darkening coefficients with those from transit observations, and discuss the results.

130.03 – **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 - 6:30 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 observed in metal-poor stars. 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 2300-5400 Å. The derived chromium abundance offset for each star is consistent with previous investigations in the literature.

130.04 – **Self-Consistent Field Model Spectra and Images for the Rapid Rotator α Cephei**

Jason P. Aufdenberg[1], K. MacGregor[2], M. Sola[1]

[1]*Embry-Riddle Aeronautical Univ.,* [2]*High Altitude Observatory.*

9:00 AM - 6:30 PM

Non-LTE synthetic radiation fields have been coupled to Self-Consistent Field (SCF) rotating star models to predict images, interferometric observables (visibilities and closure phases), spectral energy distributions (SEDs), and high-resolution spectra for comparison with rapid rotater alpha Cephei (Alderamin). SCF models include differential rotation from the interior to the surface and differ from Roche models that assume a point-mass approximation of the gravitational potential and axially symmetric uniform rotation. SCF models are parametrized by a mass, the ratio of the axial rotation rate to the critical rate, and the degree and kind (solar or anti-solar) of differential rotation. Model spectra have been computed using a parallel interpolation algorithm (coded in Fortran90 with openMPI) which maps a radiation field database onto the rotationally distorted model star. The SCF model describes the surface shape and gravitational field from the pole to the equator. The luminosity and the von Zeipel exponent

specify the variation in effective temperature with stellar latitude. The radiation field is interpolated at each point on the star for each wavelength, emergent angle, local effective, and local surface gravity.

Model images are compared to the reconstructed images of Alderamin (Zhao et al. 2009) from the Michigan InfraRed Combiner (MIRC) at the CHARA Array. Model SEDs are compared to ultraviolet, visual and near-IR spectrophotometry. High-resolution model spectra are compared Alderamin's Mg II 4481 A line from the ELODIE spectral archive. We have found models near 2.2 solar masses with anti-solar differential rotation which match simultaneously the absolute magnitude, B-V color index, and projected axial ratio measured for Alderamin. The model images differ from the observations in brightness-temperature distribution over the projected stellar surface, the strength of the Mg II line profile, and the strength of the ultraviolet continuum. This work is partially funded by the McNair Scholars Program at Embry-Riddle Aeronautical University.

130.05 – **Lifting Thor's Helmet: An X-ray/infrared Archival Study Of The Wind-blown Bubble NGC 2359**

Marcus Freeman[1], J. Kastner[1], R. Montez[1], S. Rappaport[2]

[1]*Rochester Institute of Technology,* [2]*Massachusetts Institute of Technology.*

9:00 AM - 6:30 PM

We present a combined X-ray/IR study of NGC 2359, a wind-blown bubble around a Wolf-Rayet (WR) star, with the goals of providing insight into the distribution of dust within the nebula and ascertaining its source(s) of X-ray emission. We are analyzing Spitzer and WISE infrared data in conjunction with Swift and ROSAT X-ray observations acquired from the Spitzer Heritage Archive, NASA/IPAC Infrared Science Archive, and NASA's High Energy Astrophysics Science Archive. Utilizing Spitzer and WISE data, we generated temperature and mass maps of the dust within the region. These maps reveal large dust concentrations in the main bubble, at the central WR star (WR 7), and along the southern bar of the nebula.

From the archival X-ray data, we have determined that an X-ray source that was previously attributed to WR 7 is actually associated with a 2MASS source well displaced from (57" due W of) the star, while WR 7 itself is not detected. We analyze the spectral energy distribution of the NGC 2359 X-ray source, and consider potential alternatives for its origin.

130.06 – **Luminous Stars And Variables In M31 And M33**

Roberta M. Humphreys[1], K. Weia[2]

[1]Univ. of Minnesota, [2]Ruhr-Universitaet Bochum, Germany.

9:00 AM - 6:30 PM

The results of a spectroscopic survey of Luminous Blue Variables (LBVs), candidate LBVs, hot emission line stars, and warm hypergiants in M31 and M33 is presented. Their spectra plus cross-identification with photometric surveys allows us to identify new LBV candidates and other high mass-losing stars. Several of the stars have significant infrared excesses indicating the presence of dusty circumstellar ejecta and previous high mass loss episodes. Comparison with the HR Diagram show that many of these stars fall into specific types and along recognizabe loci on the HRD.

130.07 – **The Herschel First Inventory of FIR Molecular and Atomic Species associated with Eta Carinae and the Homunculus**

Theodore R. Gull[1], P. Morris[2], K. E. Nielsen[3], J. H. Black[4], M. J. Barlow[5], B. Swinyard[5], P. Royer[6], E. Dwek[1], M. A. Bautista[7], I. Cherchneff[8]

[1]NASA/GSFC, [2]Cal Tech, [3]Catholic University of America, [4]Onsala Space Observatory, Sweden, [5]University College London, United Kingdom, [6]KU Leuven, Belgium, [7]Western Michigan University, [8]Basel University, Switzerland.

9:00 AM - 6:30 PM

We used the Herschel Observatory instruments, PACS and SPIRE , to inventory emission lines originating from the Homunculus and Eta Carinae. A plethora of lines, especially in the SPIRE spectrum, were detected.

Identified HI lines include all FIR lines from alpha (N to N-1), beta, gamma and some delta transitions.

Emission lines of multiple molecules are tentatively identified, most being nitrogen-bearing species, NH, NH+, N2H+, NH2, NH3,, HCN, HNC, CN, N2H+, but several tentative identifications of weak lines of molecules with C and O, especially CO. A number of molecules contain 13C. No strong emissions of H2O are present. Radiative transfer models must be run to confirm these and other potential molecular line identifications.

We used HIFI to obtain velocity profiles of specific lines permitting attribution to known substructures based upon optical/infrared studies: the Homunculus skirt (NH at -200 to +200 km/s), the Homunculus bipolar lobes (NH3 at -500 to -700 km/s; +500 to +700 km/s) and the central HII/ wind structure (HI at specific velocities).

Many carbon- and oxygen-bearing molecules, commonly seen in systems with overabundant carbon or oxygen, are absent or have weak emissions. Such is consistent with nebular studies that indicate the Homunculus ejecta is overabundant in nitrogen and nearly 100-fold underabundant in carbon and oxygen, depleted by CNO nuclear cycle and strong conduction in the very massive binary stellar core(s). Dust is abundant in the Homunculus, but what type of dust? Could carbon and oxygen have been further depleted by dust formation during the Great Eruption and subsequent ejections/winds? Studies of molecular abundances, coupled with models of the infrared continuum distribution will provide important clues to the dust composition.

This poster will summarize the current analysis of the Herschel spectra, their implications on CNO abundances and resultant molecular and dust formation.

130.08 – **Toward Detecting Fast Moving Massive Stars around the 30 Doradus Region**

Imants Platais[1], E. Sabbi[2], J. Anderson[2], D. J. Lennon[2], R. P. van der Marel[2], A. J. Bellini[2], S. E. de Mink[2], S. T. Sohn[2], L. R. Bedin[3]

[1]Johns Hopkins Univ., [2]Space Telescope Science Institute, [3]Osservatorio Astronomico di Padova, Italy.

9:00 AM - 6:30 PM

We have started an HST proper motion survey in the 30 Dor region of the Large Magellanic Cloud with the goal to find directions of tangential velocities of massive runaway stars and, hence, test the suggested production mechanisms (point of origin) of such stars. While the thrust of this survey is based on yet-to-be-completed two-epoch observations with the HST wide field cameras, there appears to be a considerable potential in achieving complementary aims by combining archival data from the HST WFPC2 with the latest extant observations. We report the first results of this approach and explore the level of proper-motion precision achievable with these data sets in the regime of sub-optimal images for the brighter main target stars.

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

131 – New Horizons for Science From the Moon

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

131.01 – **Gravitational Horizon(3)**

Chao Yuan Yang[1]

[1]NASA/GSFC(Retired).

9:00 AM - 6:30 PM

Anomalous decelerations of spacecraft Pioneer-10,11,etc could be interpreted as signal delay effect between speed of gravity and that of light as reflected in virtual scale, similar to covarying virtual scale effect in relative motion (http://arxiv.org /html/math-ph/0001019v5).A finite speed of gravity faster than light could be inferred (http://arXiv.org/html/physics/0001034v2). Measurements of gravitational variations by paraconical pendulum during a total solar eclipse infer the same(http://arXiv.org/html/physics/0001034v9). A finite Superluminal speed of gravity is the necessary condition to imply that there exists gravitational horizon (GH). Such "GH" of our Universe would stretch far beyond the cosmic event horizon of light. Dark energy may be owing to mutually interactive gravitational horizons of cousin universes. Sufficient condition for the conjecture is that the dark energy would be increasing with age of our Universe since accelerated expansion started about 5 Gyr ago, since more and more arrivals of "GH" of distant cousin universes would interact with "GH" of our Universe. The history of dark energy variations between then and now would be desirable(http://arXiv.org/html/physics /0001034).

In "GH" conjecture, the neighborhood of cousin universes would be likely boundless in 4D-space-time without begining or end. The dark energy would keep all universes in continually accelerated expansion to eventual fragmentation. Fragments would crash and merge into bangs, big or small, to form another generation of cousin universes. These scenarios might offer a clue to what was before the big bang.

131.02 – **Dark Ages Radio Explorer - Field Tests of a Prototype Instrument**

Abhirup Datta[1], R. Bradley[2], I. J. O'Dwyer[3], J. D. Bowman[4], J. O. Burns[1], J. Lazio[3], J. J. Bauman[5]

[1]University of Colorado, [2]National Radio Astronomy Observatory, [3]Jet Propulsion Laboratory, California Institute of Technology, [4]Arizona State University, [5]NASA Ames Research Center.

9:00 AM - 6:30 PM

The Dark Ages Radio Explorer (DARE) is a mission concept designed to measure the sky-averaged redshifted HI 21-cm signal from the cosmic Dark Ages and Epoch of Reionization between 40 - 120 MHz (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 intense human-generated radio-frequency interference (RFI) found on Earth. The science objectives of DARE include charting the history of the formation of the first stars, first accreting black holes, beginning of reionization, and end of the Dark Ages. A prototype science instrument has been constructed, consisting of bi-conical dipole antennas and a differential amplifier balun followed by a receiver and JPL-Caltech designed digital spectrometer. Extensive tests with this instrument are underway in order to improve the Technology Readiness Level (TRL) of the overall DARE instrument. Here, we present results from preliminary field tests at the National Radio Astronomy Observatory (NRAO) site in Green Bank, West Virginia. Further field tests will be performed at the Murchison Radio-astronomy Observatory (MRO) in Western Australia.

This research has been supported by the Lunar University Network for Astrophysics Research (LUNAR), headquartered at the University of Colorado Boulder and funded by the NASA Lunar Science Institute via Cooperative Agreement NNA09DB30A. Part of this research was conducted at that the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration.

131.03 – **Mcmc Signal Extraction For 21-cm Global Signal Experiments**

Geraint Harker[1]

[1]University of Colorado.

9:00 AM - 6:30 PM

Measurements of the highly redshifted 21-cm line promise to provide a great deal of information about the dark ages of the Universe, the cosmic dawn and the epoch of reionization. It is generally accepted that strong astrophysical foregrounds are a major obstacle to overcome before this promise is realised, largely because of the way they are filtered through a complicated instrumental response. A great deal of work has therefore been devoted to studying foreground removal for observations with the low-frequency radio arrays which are starting to collect data. The case of so-called 'global signal' experiments has received less attention, however. I will compare the foreground fitting problem in these two types of experiments, and describe a foreground fitting methodology which has been developed for a proposed global signal experiment, the Dark Ages Radio Explorer (DARE), which will make use of the pristine radio-frequency environment over the far side of the Moon. The method, a fully Bayesian technique based on a Markov Chain Monte Carlo code will, however, be applicable more generally to other space- and ground-based experiments, including the prototype DARE antenna being deployed in Western Australia. For ground-based experiments, we must also contend with effects from the Earth's ionosphere and low-level radio-frequency interference. I will show early results from applying our algorithm to data from the prototype and the EDGES experiment. GH is a member of the LUNAR consortium, which is funded by the NASA Lunar Science Institute (via Cooperative Agreement NNA09DB30A) to investigate concepts for astrophysical observatories on the Moon.

131.04 – **Inflatable Antennas for a Lunar Low Frequency Array**

Dayton L. Jones[1]

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

During the past decade several schemes for deploying large numbers of low frequency radio antennas on the lunar surface have been investigated. The primary scientific motivation is an eventual large array on the lunar far side to image the cosmic Dark Ages using the highly redshifted neutral hydrogen signal. This goal requires an array with thousands of individual antenna elements, requiring a simple, robust, low mass, and rapid deployment system. Several concepts are currently being studied, including rovers (autonomous or tele-operated), ballistically deployed anchors and pulleys, and shape memory materials. This paper considers the use of inflatable antennas consisting of a thin conducting layer on a tubular polyimide structure. Based on previously deployed inflatable structures in space, it seems likely that tube lengths of at least 50 meters could be unrolled on the lunar surface. A major advantage of a lunar surface location is that deflation shortly after deployment is not a problem, and no rigidization techniques are required. A fundamental constraint is the maximum distance over which an inflating tube can unroll across the lunar surface. This can be tested at lunar analog sites on Earth. An additional application of inflatable structures may be self-supporting, vertical towers to support high frequency antennas for data transport between array antenna sites. In this case post-inflation rigidization would be necessary. This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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132 – Sunyaev-Zel'dovich Effect Observations

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

132.01 – **Cosmological Simulations Of Cluster Mergers With Mock High-resolution SZE Imaging**

John Ruan[1], T. R. Quinn[1]
[1]*University of Washington.*
9:00 AM - 6:30 PM

The advent of high-resolution Sunyaev-Zel'dovich Effect imaging of galaxy clusters provides a unique probe into the rich astrophysics of the ICM out to high redshifts. To begin to understand the effects that different processes in the ICM have on the SZE signal and morphology, we present the high-resolution adiabatic cosmological simulation of a massive cluster. Using the cosmological TreeSPH code ChaNGa, we have simulated the formation of a $1.5x10^{15}$ solar mass cluster with $2.4x10^{7}$ DM and $2.1x10^{7}$ gas particles inside the virial radius at z=0. By generating mock SZE images with arcsecond scale resolution (comparable to the MUSTANG instrument on the GBT), we are able to follow the evolution of the integrated Compton Y signal as well as the morphology in the high-resolution SZE image through its last major merger at z ~0.25 to z=0. We show that the integrated Y is enhanced due to a bow shock produced by the merger, coincident with an enhanced SZE feature in the high-resolution mock images. However, the contribution of this shock feature to the integrated Y signal is overwhelmed by a gradual (but large) increase in pressure of the main cluster. While it is currently unclear whether this increase in pressure is related to the merger or due to late-time gas accretion and contraction onto the already-established DM halo, the impact of mergers in interpreting high-resolution SZE images is more obvious.

132.02 – **Mock Astro-H Simulations of Gas Motions in LCDM Clusters**

Daisuke Nagai[1], E. Lau[1]
[1]*Yale University.*
9:00 AM - 6:30 PM

In hierarchical structure formation model, clusters of galaxies are thought to form through mergers and continuous accretion of materials from large-scale structures. Modern cosmological simulations predict that internal gas motions are ubiquitous and significant in galaxy clusters. The upcoming Astro-H X-ray observatory will be able to measure these internal gas motions via Doppler shifts and broadening of X-ray spectral lines. By analyzing mock Astro-H specta of high-resolution hydrodynamical simulations, we show that the Astro-H will provide accurate measurements of peculiar velocity for relaxed clusters and reveal rich velocity substructures in merging clusters.

132.03 – **Modeling High-Resolution Sunyaev-Zel'dovich Effect Measurements of Galaxy Clusters with Cosmological Simulations**

Kaylea Nelson[1], D. Nagai[1], J. Chluba[2]
[1]*Yale University,* [2]*CITA, Canada.*
9:00 AM - 6:30 PM

In this work, we explore the power of high resolution Sunyaev-Zel'dovich effect (SZE) observations to probe the evolution of cluster gas structure. Utilizing mock SZE analyses of high-resolution Eulerian cosmological simulations of galaxy clusters, we show that kinematic SZE by internal gas motions and relativistic correction introduce significant, frequency-dependent effects on morphological and substructure properties of the thermal SZE signal, especially in massive clusters undergoing mergers. Our results indicate that these effects must be taken into account when analyzing the newly discovered SZ-selected clusters.

132.04 – **NIKA: A High-Resolution Millimetre Camera for the IRAM 30m Telescope**

F. Xavier Desert[1], P. Mazzotta[2], C. NIKA[3]
[1]*Institut de Planetologie et d'Astrophysique de Grenoble, France, France,* [2]*Dipartimento di Fisica, Italy,* [3]*European Consortium, France.*
9:00 AM - 6:30 PM

A consortium of European laboratories lead by Alain Benoit (CNRS-Institut Néel, Grenoble) is building a new continuum dual-band camera for the IRAM 30m telescope. It will map the sky simultaneously at 150 and 230 GHz (2 and 1.3 mm), with an angular resolution of 15 and 10 arcseconds and a field-of-view of 6.5 arcminutes in diameter. It is based on new Kinetic Inductance Detector arrays (1000 pixels at 2 mm, 3000 at 1.3 mm) cooled to 100 mK. It will provide in 2015 a high-resolution ground-based follow-up of the numerous clusters of galaxies detected with the SZ effect by the Planck satellite and ACT at the same frequency (150 GHz). A prototype camera is already being tested that provides a sensitivity for the y compton parameter of about 1E-5 (1 sigma, 1 hour, 1 beam).

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133 – Catalogs and Surveys

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

133.01 – **CANDELS: Measuring Photometric Redshifts And Stellar Masses For Deep Surveys**

Tomas Dahlen[1], B. Mobasher[2], CANDELS Collaboration
[1]*STScI,* [2]*UCR.*
9:00 AM - 6:30 PM

We present results from the Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) photometric redshift and SED fitting tests. The aim of the performed tests is to understand systematic effects affecting the accuracy of photometric redshifts as well as the estimates of galaxy stellar masses for large deep surveys.

133.02 – **Optical Properties Of Millimeter-wave Sources From The SPT/ACT Surveys**

John Patrick Hughes[1], F. Menanteau[1]
[1]*Rutgers Univ..*
9:00 AM - 6:30 PM

We use multiband optical imaging from the NOAO/CTIO Blanco 4-m telescope to determine possible counterparts and lensing candidates for millimeter-wave sources from the South Pole Telescope. In this work we examine the ~60 synchrotron- and ~20 dust-dominated sources (above a signal-to-noise of 4.5) that overlap the 5-hr field of the Southern Cosmology Survey. We find secure optical counterparts for nearly 60% of the synchrotron sources. A good fraction of the secure counterparts (approx. 30%) are relatively bright nearby radio galaxies. We specifically examine the local environments of the dust-dominated sources for evidence of intervening galaxies or galaxy clusters that could be providing a significant lensing magnification of the light from a high-redshift background galaxy. We find plausible lensing candidates (nearly all of which are groups or small clusters) for at least one-third of the dusty sources that are not clearly associated with Galactic sources or very nearby dusty galaxies. Nearly all of the brightest dusty sources at 1.4 mm are associated with lensing systems.

133.03 – **Identifying Microlenses In Large, Non-uniformly Sampled Surveys: The Case Of PTF**

Adrian M. Price-Whelan[1], M. Agüeros[1], A. Fournier[2], E. Ofek[3], R. Street[4]
[1]*Columbia University,* [2]*University of California Santa Barbara,* [3]*Weizmann Institute of Science, Israel,* [4]*Las Cumbres Observatory Global Telescope Network, Inc..*
9:00 AM - 6:30 PM

Many current photometric, time-domain surveys are driven by specific goals, such as supernova searches, transiting exoplanet discoveries, or stellar variability studies, which set the cadence with which individual fields get re-imaged. In the case of the Palomar Transient Factory (PTF), several such sub-surveys are being conducted in parallel, leading to an extremely non-uniform sampling gradient over the survey footprint of nearly 20,000 deg^2: while the typical 7.26 deg^2 PTF field has been imaged 15 times, ~1000 deg^2 of the survey has been observed more than 150 times. We use the existing PTF data to study the trade-off between a large survey footprint and irregular sampling when searching for microlensing events, and to examine the probability that such events can be recovered in these data. We conduct Monte Carlo simulations to evaluate our detection efficiency in a hypothetical survey field as a function of both the baseline and number of observations. We also apply variability statistics to systematically differentiate between periodic, transient, and flat light curves. Preliminary results suggest that both recovery and discovery of microlensing events are possible with a careful consideration of photometric systematics. This work can help inform predictions about the observability of microlensing signals in future wide-field time-domain surveys such as that of LSST.

133.04 – **The HST Object Catalog for Multicolor and Time-Domain Studies**

Tamas Budavari[1], S. Lubow[2]
[1]*Johns Hopkins University,* [2]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

We present a new crossmatch catalog of the Hubble Legacy Archive (HLA) to enable multicolor and time-domain studies. The HLA project has processed more than 50,000 combined visit-level images of the Hubble Space Telescope (HST) to provide separate sources lists for ACS and WFPC2. The observations often overlap, which has a huge potential for a wide range of astronomy analyses. First we collected overlapping images into groups, e.g., Eta Car, and matched the sources within the groups based on their location on the sky. We numerically refine the astrometric calibration of each visit to establish a better common coordinate system for each group. Our optimization greatly enhances the precision of the measurements; the errors often shrink by a factor of 10 from 0.1 arc seconds to subpixel scales. Using the improved positions, we apply Bayesian hypothesis testing to efficiently find the most likely matches even in regions with hundreds of overlapping images. The catalog will be publicly available online.

133.05 – **Rapid Rotators among APOGEE Red Giants**

Dmitry Bizyaev[1], J. K. Carlberg[2], D. L. Nidever[3], S. R. Majewski[3], M. D. Shetrone[4], V. V. Smith[5], R. J. Patterson[3], K. Cunha[6], J. A. Holtzman[7], R. W. O'Connell[3], K. Pan[1]

[1]Apache Point Observatory / NMSU, [2]Carnegie Institution of Washington, [3]University of Virginia, [4]McDonald Observatory, [5]National Optical Astronomy Observatory, [6]Observatorio Nacional, Brazil, Steward Observatory/NOAO, [7]New Mexico State University.

9:00 AM - 6:30 PM

The Apache Point Galactic Evolution Experiment (APOGEE) is a part of the SDSS-III survey. APOGEE is a high-resolution (R ~ 22,500) multi-fiber near-infrared (1.5-1.7 mu) spectroscopic survey of 100,000 candidate stars selected from all populations of the Milky Way. The majority of the APOGEE targets are expected to be red giants. Past studies have shown that a small fraction (1-2%) of red giant stars shows rather high projected rotational velocities (vsini > 10 km/s), whereas most of the red giants rotates slowly (vsini ~ 2 km/s). The unusual rapid rotation for this type of giants may indicate that they experience either a rare and poorly understood stage of evolution, or swallow low-massive companions (such as brown dwarfs or planets). Due to the combination of high resolution and high signal-to-noise ratio (SNR), the APOGEE provides us with a unique possibility to study the stellar rotation for a large sample of cool stars, and particularly to uncover the largest sample of rapidly rotating red giants to date. Even conservative estimates of the fraction of rapidly rotating giants imply that we can increase the number of known rapid rotators by almost an order of magnitude. For the first half of a year of science operations, which started in September 2011, APOGEE has produced spectra of more than 20,000 unique science targets. These single-visit spectra have lower than final SNR, and they will be improved after two more visits to the same target during the next two years of observations to reach the program SNR. In this paper we present the first sample of rapidly rotating red giants selected from reduced APOGEE spectra presently available. We test different approaches to the estimation of the spectral line broadening and rotational velocity.

133.06 – **The AAVSO Photometric All-Sky Survey Completes the Sky**

Arne A. Henden[1], T. C. Smith[2], S. E. Levine[3], D. Terrell[4]

[1]AAVSO, [2]DRO, [3]Lowell Observatory, [4]SwRI.

9:00 AM - 6:30 PM

The AAVSO All-Sky Photometric Survey (APASS) will calibrate the entire sky in five passbands: Johnson B and V, and Sloan g,r,i. The magnitude range is 10<V<17, with photometric accuracy near 0.02mag at the bright end. Pixel size is 2.6arcsec. The survey has been underway for about 18 months, and has now achieved the milestone of covering the entire sky a minimum of two times, with approximately 40 million objects in the current catalog. The final survey will have four visits per object, and will be completed in about two years. We may either extend the survey to include brighter objects or more filters, depending on funding. Data Release 6 can be freely downloaded from http://www.aavso.org/apass. The poster will give information about the survey, and will show field coverage and statistical information regarding the photometric and astrometric accuracy of the current release.

134 – Molecular Clouds, HII Regions, Dust and the ISM

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

134.01 – **Small Scale HI Structure: Multi-epoch Green Bank Pulsar HI Absorption Observations**

Anthony Howard Minter[1]

[1]NRAO.

9:00 AM - 6:30 PM

Multi-epoch pulsar HI absorption measurements can be used to search for small scale HI structure in the ISM due to pulsar's generally large proper motions. I will present results from observations with the Green Bank Telescope over the last decade.

134.02 – **Three New Intermediate-Velocity Molecular Clouds in the Northern Galactic Hemisphere**

Allison J. Smith[1], L. Magnani[1]

[1]University of Georgia.

9:00 AM - 6:30 PM

We report the detection in the CO(J=1-0) transition of 3 new intermediate-velocity molecular clouds at high Galactic latitude in the Northern Galactic Hemisphere. These 3 objects nearly double the number of previously-known high-latitude molecular clouds with intermediate velocities (v_${LSR}$ le $-$20 km/s). In order to detect the CO(J=1-0) line, N(H$_2$) values of at least 10^{19} cm^{-2} are necessary, implying that the molecular/atomic fraction of these objects is significant; these clouds are primarily molecular, in contrast to the primarily atomic lines of sight with log N(H$_2$) < 17.3 detected in absorption by FUSE. The three molecular clouds are projected on and likely associated with a previously-known intermediate velocity feature known as the Intermediate Velocity Spur that may extend to the Galactic Halo. All three clouds are located in a 12 deg x 4 deg region and may be related. Morphologically, they are embedded in a large filamentary dust structure that extends past b = +60 deg.

134.03 – **Probing Our Heliospheric History II**

Katherine Wyman[1], S. Redfield[2]

[1]Smithsonian Astrophysical Observatory, [2]Wesleyan University.

9:00 AM - 6:30 PM

A physical relationship between our local interstellar medium (ISM), galactic cosmic rays (GCR), and our planetary environment has long been a subject of interest to the astronomical community. Clouds of sufficient density to compress the heliosphere to within 1 AU are commonly seen throughout the galactic environment, including within the Local Bubble (LB). Such a compression would lead to an increase in the GCR flux at 1 AU and would have drastic consequences for many planetary processes such as atmospheric chemistry, lightning production, cloud cover, and DNA mutation rates for surface organisms. Prior to this work, we derived a column density profile of the ISM toward 49 bright stars along a narrow cone centered on the historical solar path. High resolution spectra were taken of NaI and CaII absorption out to a distance of 610 pc, with a median separation distance of 11 pc between adjacent stars. No absorption is seen out to a distance of 120 pc (consistent with the LB), but a complex number of absorbers is seen beyond. We now present the detection of several distinct clouds, their associated column densities, radial velocities, inferred distances, and size constraints. This combination of cloud properties allows us to derive a volume density profile of the ISM in the Sun's "rear-view mirror," which represents one plausible record of actual ISM encounters for the Sun. We also make use of empirical relations to determine the effect these clouds would have on the historical heliosphere. Our analysis suggests that within the last 10 million years, if the Sun encountered a cloud with the same properties as we have detected along the solar historical trajectory, the Sun's termination shock would have resided inside the orbit of Uranus, with a GCR flux at Earth an order of magnitude greater than it is currently.

134.04 – **CO and H2O Ices Towards Field and Embedded Stars in ρ Ophiuchi and Taurus**

Steven Lentine[1], D. Horne[1], D. Whittet[1], J. Chiar[2]

[1]Rensselaer Polytechnic Institute, [2]SETI Institute.

9:00 AM - 6:30 PM

In an ongoing study of ices in molecular clouds, we present 2.2-5.0μm spectra of 11 embedded young stellar objects and 5 field stars toward the ρ Ophiuchi and Taurus clouds. The spectra were obtained with the SpeX instrument on the NASA Infrared Telescope Facility at a mean resolving power of ~1500. We report H2O ice absorption at 3.05μm towards 15 sources in our sample and CO ice absorption at 4.67μm toward 7 sources. We utilize 49 H2O and 26 prior CO observations from available data sets and compare derived abundances for signs of chemical processing between the field and embedded sources within each cloud. We find significant differences between H2O and CO abundances in ρ Ophiuchi and Taurus, attributed to the disparate structure, star forming activity, and (radiation) environments of the clouds. Our results suggest that ice column densities are far less well correlated with dust column (as measured by Av) in ρ Ophiuchi compared with Taurus. This work was supported by the NASA Astrobiology Institute.

134.05 – **Estimates of Dust and 13CO Radial Volume Density Profiles in Nearby Molecular Clouds**

Marko Krco[1]

[1]Cornell University.

9:00 AM - 6:30 PM

The relation between dust and gas bears significance in many questions relating to the chemistry of the ISM and molecular clouds in particular. A perennial problem in understanding the relation is that the bulk of our measurements come in the form of integrated intensity or column density maps, yet most chemical processes depend on volume densities of the species in question. Radial volume density profiles of dust and ^{13}CO are obtained, within certain limitations, for several nearby molecular clouds. A new, ***geometry-independent***, technique is employed to obtain the radial volume density profiles. This technique provides several advantages over previous methods. A direct comparison between stellar reddening due to dust and ^{13}CO emission is made throughout each cloud. Implications for temperature variations and the dust to gas ratio throughout the interior of molecular clouds are discussed as well as limitations on the presence of ^{13}CO freezing onto dust grains.

134.06 – **The Fate of Ionizing Photons in Two Different Star Formation Complexes in the SMC**

Audrey Simmons[1], R. Walterbos[2], E. Sabbi[3], S. Points[4], A. Nota[3]

[1]*New Mexico State University / Apache Point Observatory,* [2]*New Mexico State University,* [3]*STScI,* [4]*Cerro Tololo Inter-American Obs., Chile.*
9:00 AM - 6:30 PM

The SMC is the closest galaxy to enable study star formation and feedback with the ISM in a low-metallicity environment. In this project we analyze the fate of ionizing photons in two different regions in the SMC. NGC346 is the largest and most massive HII region in the SMC, containing more than half the known O stars. NGC602 is of similar young age, but an order of magnitude less luminous and further out in the "wing" of the SMC. We study the ionization balance in these two objects. Of particular interest is the question of the source of ionization of the diffuse ionized medium, which contributes a substantial fraction of the Halpha luminosity of galactic disks. We want to determine how much of the ionization radiation may be leaking out of the HII regions, and also if isolated massive stars in the surroundings contribute to the ionization of diffuse gas outside HII regions. We characterize the ionized gas distribution in the two environments from CTIO and HST images of the emission line gas. We compile information on spectral types of the stars in two ways. Many of the stars have ground-based spectral type determinations, but we also explore using the HST photometry to derive spectral types by calibrating the photometric data against spectral types where independently known. From these data, we analyze the amount of predicted ionizing Lyman continuum radiation in comparison to the observed H-alpha emission within several HII sub-regions and the nearby diffuse interstellar gas.

134.08 – **The Environmental Dependence Of UV Extinction In The SMC**

Edward L. Fitzpatrick[1], K. D. Gordon[2], D. L. Massa[2], D. J. Lennon[3], K. Sandstrom[4], G. C. Clayton[5], K. Misselt[6], R. Bohlin[2]

[1]*Villanova University,* [2]*Space Telescope Science Institute,* [3]*Space Telescope Science Institute - ESA,* [4]*Max Planck Institut fur Astronomie, Germany,* [5]*Louisiana State University and A&M College,* [6]*University of Arizona.*
9:00 AM - 6:30 PM

Observations of both nearby and distant galaxies, including our own Milky Way, have shown that wide variations in the UV interstellar extinction properties within and among galaxies are the norm, indicating wide ranges in the properties of galactic dust grain populations. UV extinction curves show a variety of forms, including strong and weak 2175 Å bumps, steep and flat mid-UV extinction, and strong and weak far-UV curvature. The Small Magellanic Cloud (SMC) is known to have UV extinction - and, therefore, dust grain populations - spanning nearly the full range of observed properties. This, coupled with its nearby location, makes the SMC an ideal subject for a study of the correlation between UV extinction and other properties of individual sightlines (e.g., gas-to-dust ratio, presence of molecular material, star formation activity, etc.). Such a study will lead to an increased understanding of the influence of environmental factors on the dust grain populations and a better characterization of the distinct processes which modify the grains. In this poster, we present initial results from an analysis of STIS spectra obtained in a Cycle 18 observing program (Program ID 12258; K. Gordon, PI) for 15 previously unobserved SMC stars, combined with STIS spectra for 6 other stars obtained in earlier cycles. The derivation of the extinctions curves and their uncertainties is discussed and the curve morphology examined, along with preliminary environmental correlations. Interesting early results of the analysis are (1) that none of the new extinction curves - which probe a variety of sites in the SMC - show a prominent 2175 Å bump and (2) the detection of a new morphological class of extinction curves, which feature flat UV extinction with nearly non-existent bumps and far-UV curvature.

134.09 – **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 - 6:30 PM

With a long duration balloon launch from Antarctica in January 2012, the Stratospheric TeraHertz Observatory (STO) has completed its maiden science flight. 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 announced this Fall 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.

134.1 – **Dense Core Properties in the Serpens North Molecular Cloud**

Kevin Hardegree-Ullman[1], Y. L. Shirley[1], E. W. Rosolowsky[2], K. J. Burleigh[1], J. H. Bieging[1], E. E. Hardegree-Ullman[3], W. M. Schlingman[1]

[1]*University of Arizona,* [2]*University of British Columbia at Okanagan, Canada,* [3]*Rensselaer Polytechnic Institute.*
9:00 AM - 6:30 PM

We mapped 35 dense cores, identified by the 1.1mm Bolocam survey (Enoch et al. 2007) and the Sptizer c2d Legacy project (Evans et al. 2003), in the Serpens North Molecular Cloud using the N_2H^+ J = 1 -> 0 transition observed with the Arizona Radio Observatory 12m telescope. We present source properties for the 20 Class 0 protostars and 15 dense starless cores, derived from N_2H^+ measurements. For our calibration, we have updated the equation for the brightness temperature of Venus, T_{Venus} = 266.4K + (245K/(1 + (ν[GHz]/64.7)^2)), which is applicable to the frequency range from 23GHz to 900GHz. Additionally, we have observed all 35 cores in the (J, K) = (1, 1) and (2, 2) lines of NH_3 using the 100m Green Bank Telescope. From the NH_3 observations we are able to determine kinetic temperatures of gas in these dense cores. We make a direct comparison between the properties of these two dense gas tracers. We also compare our measurements of N_2H^+ linewidths to ^{12}CO and ^{13}CO J = 2 -> 1 linewidths obtained by Burleigh et al. using the 10m Submillimeter Telescope on Mt. Graham in Arizona to place constraints on turbulence within the dense cores and surrounding molecular cloud filaments. This research was supported in part by the University of Arizona 2010-2011 NASA Space Grant program.

134.11 – **Small-Scale Structure in the Interstellar Medium Traced by Formaldehyde Absorption**

Esteban Araya[1], M. Goss[2], N. Dieter-Conklin[3]

[1]*Western Illinois University,* [2]*National Radio Astronomy Observatory,* [3]*Emeritus, Radio Astronomy Laboratory, University of California.*
9:00 AM - 6:30 PM

We report VLA observations of Galactic formaldehyde absorption toward four extragalactic radio sources to study the small-scale distribution of molecular gas in the foreground clouds. Observations of formaldehyde absorption toward the same sources were conducted in the 1990s by Marscher and collaborators. We used these archive data together with our new observations to study variability in the line profiles over a time-scale of almost two decades. The variability is due to changes in the projected line-of-sight towards the radio sources, caused by the combined motion of the foreground molecular clouds and the Solar System around the Galaxy. We found changes in the line profiles indicative of sub-structure within the molecular clouds. Our results are consistent with molecular material distributed in filaments or cores, characterized by size-scales smaller than ~40,000 AU (0.2 pc) and greater than ~100 AU.

134.12 – **AZTECAN C3PO: Arizona Three-millimeter Educational C18O And N2H+ Cold Core Census of Planck Objects**

Amanda Walker-LaFollette[1], Y. L. Shirley[1], K. K. Hardegree-Ullman[1], A. P. M. Towner[1], S. C. Wallace[1], C. W. Smith[1], J. D. Turner[1], A. N. Robertson[1], C. L. Austin[1], L. C. Small[1], T. M. Carleton[1], A. M. McGraw[1], M. J. Daugherty[1], B. C. Guvenen[1], K. L. Johnson[1], B. E. Crawford[1], B. M. Smart[1]

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

The Planck satellite is studying the power spectrum of the Cosmic Microwave Background (CMB), and has found foreground contamination including dust emission from the Galaxy. The Planck Cold Core Team has been cataloging and characterizing this foreground emission. An initial catalog of over 10,000 objects, the Cold Core Census of Planck Objects (C3PO), was released from the first year of data. A subset of 915 cold cores with dust temperatures of T_d < 14K and SNR > 15 was selected from this catalog, and called the Early Cold Core (ECC) Catalog.

Ground-based follow-up observations of these cores are needed to determine their size, mass, source geometry (filamentary, multiple cores, etc.), and kinematic properties (degree of turbulence, etc.). Using the Arizona Radio Observatory 12m radio telescope, we mapped a sub-sample of the ECC at 1′ resolution in the dense gas tracers $C^{18}O$ J=1-0 and N_2H^+ J=1-0. These tracers complement each other, with CO depleting in very cold, dense environments where N_2H^+ may be abundant. While we detected most of the cores observed in $C^{18}O$, we find that N_2H^+ emission is very weak toward many Planck cold cores. We present here the initial results from our mapping survey. This project is the main component of Amanda Walker-LaFollette's NASA Space Grant internship research.

134.13 – **The Structure of Carbon in the Interstellar Medium**

Jean E. Chiar[1], A. G. G. M. Tielens[2]

[1]*SETI Institute,* [2]*Leiden Observatory, Netherlands.*
9:00 AM - 6:30 PM

We have used the astronomical data for the aliphatic and aromatic hydrocarbon absorption features in the diffuse ISM toward the Galactic Center to place observational constraints on the material characteristics of carbon grains in the ISM. Carbonaceous materials show a great diversity in properties because the four valence electrons of carbon can exist in three hybridization forms, resulting in sp3, sp2, and sp1 bonds. The physical properties of Hydrogenated Amorphous Carbon (HAC) materials are intimately linked to their microscopic structure. HAC films consist of a strongly cross-linked three-dimensional network where aromatic clusters are bonded through aliphatic hydrocarbon chains. The tetrahedrally bonded carbon (sp3 hybrids) leads to a three-dimensional network that provides the material hardness, while the graphitic clusters (sp2 hybrids) in the network set the optical properties because they control the optical gap of the material. The various forms of carbonaceous materials are then distinguished by their H content, the fraction of sp2 and sp3 carbon, and the size of the aromatic clusters. We have measured the fraction of sp2, sp3 and H in the material using the observed aromatic and aliphatic hydrocarbon absorption features, and plotted the fractional composition on a ternary diagram. In this presentation, we discuss how we use the ternary diagram to determine the physical properties of the galactic interstellar carbonaceous dust.

134.14 – **Interstellar Dust Plumes in the Heliosphere**

Priscilla C. Frisch[1], J. D. Slavin[2], J. Heerikhuisen[3], N. V. Pogorelov[3], G. P. Zank[3], H. Mueller[4], W. Reach[5], K. Avinash[3]
[1]Univ. of Chicago, [2]Harvard-Smithsonian Center for Astrophysics, [3]Univ. of Alabama, [4]Dartmouth College, [5]SOFIA/USRA.
9:00 AM - 6:30 PM

The tenuous interstellar medium surrounding the Sun is host to a magnetic field that distorts the heliosphere and affects the trajectories of charged interstellar dust grains interacting with the solar wind. Interstellar dust grains that encounter the heliosphere may be diverted around heliopause or penetrate it, depending on their charge-to-mass ratio. New 3D calculations of the trajectories of interstellar dust encountering the heliosphere predict the grain density distribution for the two opposite magnetic polarities of the solar wind. The resulting distributions depend on both the magnetic phase of the solar cycle and grain size. During the defocusing polarity, the Lorentz force drives positively charged grains away from the ecliptic plane. For this polarity, grains with radius about 0.2 microns are concentrated in the outer heliosphere where they are swept towards the downwind direction as high-latitude dust plumes. During the opposite focusing polarity, these grains instead are swept through the outer heliosphere into the downwind direction at low ecliptic latitudes, with an arc-like feature forming towards the nose of the heliosphere (defined as the direction from which interstellar gas and dust flow into the heliosphere). During both polarities, the smallest grains are completely excluded from the heliosphere, while the largest grains form a focusing tail downwind of the Sun. The underlying heliosphere model is a 3D MHD model that incorporates the neutral interstellar hydrogen flowing into the heliosphere in a kinematically self-consistent way. This research has been supported by NASA and by the IBEX mission as part of NASA's Explorer Program.

134.15 – **Assessing The Presence, Charge And Size Of Pahs In Dense Clouds**

Tin Tran[1], J. E. Chiar[2], E. Peeters[3], A. Ricca[4], L. J. Allamandola[5], A. L. Mattioda[5], M. Kress[6]
[1]SETI Institute, San Jose State University, [2]SETI Institute, [3]University of Western Ontario, Canada, [4]SETI Institute, NASA Ames Research Center, [5]NASA Ames Research Center, [6]San Jose State University.
9:00 AM - 6:30 PM

PAHs are observed to be present and abundant in nearly all phases of the galactic and extragalactic interstellar medium. To date, PAH emission bands at 3.28, 6.2, 7.7, 8.6, and 11.2 micron, have been most easily detected in regions where individual gas phase PAH molecules (neutrals and ions) become highly vibrationally excited by the ambient radiation field. While PAHs and closely related aromatic materials should be present throughout dense interstellar regions, PAH emission is quenched in cold dark dense clouds. In these regions, most PAHs should efficiently condense out onto dust grains, either as ‘pure’ solids or as ‘guest molecules’ in icy grain mantles, much as is the case for most other interstellar molecules and therefore give rise to IR absorption bands rather than emission features. Spectroscopic observations of dense cloud lines of sight show prominent absorption features at 6.0 µm and 6.8 µm. These absorption features are seen in infrared spectra of young stellar objects (YSOs) and quiescent dense cloud regions. While ice species can account for some of the absorption, much of the absorption remains unidentified. Since fundamental PAH vibrational modes fall in the wavelength region of the unidentified absorption, and they are ubiquitous constituent of the ISM, they are good candidates to account for some of this absorption. Using the NASA Ames PAH Infrared Spectral Database, which contains computationally and experimentally generated spectra of many PAH species that vary in size and charge state, we aim to determine the contribution of PAHs to the unidentified absorption. In addition, we will investigate differences in the physical characteristics (size, charge state) of PAHs in quiescent dense cloud versus YSO environments. This poster discusses the preliminary results of this project for which we gratefully acknowledge funding by NASA’s ADAP program and the URSA program, funded by the NASA EPOESS program.

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135 – Instrumentation, Computation and Data Handling

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

135.01 – **Extreme Doppler Precision With Octagonal Fiber Scramblers**

Julien Spronck[1], Z. A. Kaplan[1], D. A. Fischer[1], C. Schwab[1], A. E. Szymkowiak[1]
[1]Yale University.
9:00 AM - 6:30 PM

The detection of Earth-like exoplanets with the radial velocity method requires extreme Doppler precision and long-term stability in order to measure tiny reflex velocities in the host star. Recent planet searches have led to the detection of so called “super-Earths” (up to a few Earth masses) that induce radial velocity changes of about 1 m/s. However, the detection of true Earth analogs requires a precision of 10 cm/s. One of the factors limiting Doppler precision is variation in the Point Spread Function (PSF) from observation to observation due to changes in the illumination of the slit and spectrograph optics. Thus, this stability has become a focus of current instrumentation work. Fiber optics have been used since the 1980’s to couple telescopes to high-precision spectrographs, initially for simpler mechanical design and control. However, fiber optics are also naturally efficient scramblers. Our research is focused on understanding the scrambling properties of fibers with different geometries. We have characterized circular and octagonal fibers in terms of their throughput, focal ratio degradation, modal noise, near-field and far-field distributions. We also have characterized these fibers using an actual bench-mounted high-resolution spectrograph: the Yale Doppler Diagnostics Facility (YDDF). In this paper, we summarize all these results that show clear improvements in instrumental profile stability using non-traditional fiber geometries.

We acknowledge the support of the Planetary Society, NSF and NASA.

135.02 – **An Innovative Combination of Fiber Scrambling and Image Slicing for High Resolution Spectrographs**

Zachary Kaplan[1], J. F. P. Spronck[1], D. A. Fischer[1], C. Schwab[1]
[1]Yale University.
9:00 AM - 6:30 PM

The detection of Earth-like exoplanets with the radial velocity method requires extreme Doppler precision and long-term stability in order to measure tiny reflex velocities in the host star. Recent planet searches have led to the detection of so called “super-Earths” (up to a few Earth masses) that induce radial velocity changes of about 1 m/s. However, the detection of true Earth analogs requires a precision of 10 cm/s. Image slicers have been used since 1938 to increase spectral resolution of the spectrograph while minimizing light losses by “slicing” the star image into a spot of less width and greater length. However, slicing the image creates a multiple-peak order in the cross-dispersion direction, which ultimately impacts modeling of the extracted spectrum. Here we present the design of a modified Bowen-Walraven type image slicer that re-images the sliced spot onto a rectangular optical fiber, using the exit of that fiber to feed a spectrograph. Such a fiber preserves the narrow width in the image plane while creating stable illumination in the pupil plane. The fiber also provides good scrambling of the incoming light. Scrambling refers to a fiber’s ability to produce an output beam independent of input. This is of particular importance for precise radial velocities, as fiber scramblers help to decouple the spectrograph from errors such as guiding, focusing or seeing changes; thus improving the spectrograph stability. The resulting pseudo-slit is half the original slit width, doubling the spectral resolution while eliminating losses associated with a narrow slit. Such a design could be implemented on many current high resolution spectrographs. We acknowledge the support of the Planetary Society, NSF and NASA.

135.03 – **KAPAO: A Natural Guide Star Adaptive Optics System for Small Aperture Telescopes**

Scott A. Severson[1], P. I. Choi[2], E. Spjut[3], D. S. Contreras[2], B. N. Gilbreth[1], L. P. McGonigle[2], W. A. Morrison[2], A. R. Rudy[2], A. Xue[3], C. Baranec[4], R. Riddle[4]
[1]Sonoma State University, [2]Pomona College, [3]Harvey Mudd College, [4]California Institute of Technology.
9:00 AM - 6:30 PM

We describe KAPAO, our project to develop and deploy a low-cost, remote-access, natural guide star adaptive optics system for the Pomona College Table Mountain Observatory (TMO) 1-meter telescope. The system will offer simultaneous dual-band, diffraction-limited imaging at visible and near-infrared wavelengths and will deliver an order-of-magnitude improvement in point source sensitivity and angular resolution relative to the current TMO seeing limits. We have adopted off-the-shelf core hardware components to ensure reliability, minimize costs and encourage replication efforts. These components include a MEMS deformable mirror, a Shack-Hartmann wavefront sensor and a piezo-electric tip-tilt mirror. We present: project motivation, goals and milestones; the instrument optical design; the instrument opto-mechanical design and tolerances; and an overview of KAPAO Alpha, our on-the-sky testbed using off-the-shelf optics.

Beyond the expanded scientific capabilities enabled by AO-enhanced resolution and sensitivity, the interdisciplinary nature of the instrument development effort provides an exceptional opportunity to train a broad range of undergraduate STEM students in AO technologies and techniques. The breadth of our collaboration, which includes both public (Sonoma State University) and private (Pomona and Harvey Mudd Colleges) undergraduate institutions has enabled us to engage students ranging from physics, astronomy, engineering and computer science in the all stages of this project. This material is based upon work supported by the National Science Foundation under Grant No. 0960343.

135.04 – **KAPAO-Alpha: An On-The-Sky Testbed for Adaptive Optics on Small Aperture Telescopes**

Will Morrison[1], P. I. Choi[1], S. A. Severson[2], E. Spjut[3], D. S. Contreras[1], B. N. Gilbreth[2], L. P. McGonigle[1], A. R. Rudy[1], A. Xue[3], C. Baranec[4], R. Riddle[4]
[1]Pomona College, [2]Sonoma State University, [3]Harvey Mudd College, [4]California Institute of Technology.
9:00 AM - 6:30 PM

We present initial in-lab and on-sky results of a natural guide star adaptive optics instrument, KAPAO-Alpha, being deployed on Pomona College’s 1-meter telescope at Table Mountain Observatory.

The instrument is an engineering prototype designed to help us identify and solve design and integration issues before building KAPAO, a low-cost, dual-band, natural guide star AO system currently in active development and scheduled for first light in 2013. The Alpha system operates at visible wavelengths, employs Shack-Hartmann wavefront sensing, and is assembled entirely from commercially available components that include: off-the-shelf optics, a 140-actuator BMC deformable mirror, a high speed SciMeasure Lil’ Joe camera, and an EMCCD for science image acquisition. Wavefront reconstruction operating at 1-kHz speeds is handled with a consumer-grade computer running custom software adopted from the Robo-AO project. The assembly and integration of the Alpha instrument has

been undertaken as a Pomona College undergraduate thesis. As part of the larger KAPAO project, it is supported by the National Science Foundation under Grant No. 0960343.

135.05 – **USNO Robotic Astrometric Telescope (URAT) Underway**

Charlie T. Finch[1], G. Bredthauer[2], M. DiVittorio[1], F. Harris[1], T. Rafferty[1], G. Wieder[1], N. Zacharias[1]

[1]*US Naval Observatory,* [2]*Semiconductor Technology Associates, Inc..*

9:00 AM - 6:30 PM

The USNO Robotic Astrometric Telescope (URAT) is currently deployed at the Naval Observatory Flagstaff Station (NOFS). First light was achieved in 2011 at USNO in Washington DC. A decade long automated, low-cost, observing program is envisioned at Cerro Tololo Inter-American Observatory (CTIO) after completion of the northern hemisphere from NOFS. URAT will provide accurate reference stars, parallaxes and improved proper motions before Gaia, be able to observe stars brighter than the Gaia limit (needed for guiding of spacecraft) and observe astrometric binaries and expolanet "wobbles" with long time span coverage.

Utilizing the red-lens from the UCAC program, the telescope has been completely redesigned with a new tube assembly, upgraded mount and new electronics. The new 4-shooter camera consists of 4 large 10,560 by 10,560 pixel CCDs (ST1600B). A single URAT exposure covers 28 square degrees with a resolution of 0.9 arcsec/pixel.

A single observing precision of 20 mas for high S/N stars and a limiting magnitude of r = 18 is expected, with 10-fold sky overlaps per year. The clocked anti-blooming mode of the camera extends the dynamic range for astrometry for bright stars. The URAT instrument also contains a neutral density spot on the filter allowing observations of bright stars to about 1st magnitude.

A first data release is expected by the end of 2013.

135.06 – **The Chromospheric Magnetometer ChroMag**

Christian Bethge[1], A. G. de Wijn[1], S. W. McIntosh[1], S. Tomczyk[1], R. Casini[1]

[1]*High Altitude Observatory.*

9:00 AM - 6:30 PM

We present the Chromosphere Magnetometer (ChroMag), which is part of the Coronal Solar Magnetism Observatory (COSMO) proposed by the High Altitude Observatory (HAO) in collaboration with the University of Hawaii and the University of Michigan. ChroMag will perform routine measurements of chromospheric magnetic fields in a synoptic manner. A prototype is currently being assembled at HAO. The main component of the instrument is a Lyot-type filtergraph polarimeter for both on-disk and off-limb polarization measurements in the spectral lines of H alpha at 656.3 nm, Fe I 617.3 nm, Ca II 854.2 nm, He I 587.6 nm, and He I 1083.0 nm. The Lyot filter is tunable at a fast rate. This allows to determine line-of-sight velocities in addition to the magnetic field measurements. The instrument has a field-of-view of up to 2.5 solar radii and will acquire data at a cadence of less than 1 minute and at a spatial resolution of 2 arcsec. The community will have open access to the data as well as to a set of inversion tools for an easier interpretation of the measurements. We show an overview of the proposed instrument and first results from the protoype.

135.07 – **Characterization of the Ultraviolet Imaging Telescope (UVIT) Detector Performance at the University of Calgary**

Denis A. Leahy[1], J. Postma[1], J. Hutchings[2]

[1]*Univ. of Calgary, Canada,* [2]*National Research Council, Herzberg Institute of Astrophysics, Canada.*

9:00 AM - 6:30 PM

The Ultraviolet Imaging Telescope is one of the instruments that will be on board the Indian Space Research Organization's space-based telescope ASTROSAT and images the sky in far UV through optical wavelengths. ASTROSAT includes X-ray instruments with sensitivity in soft to hard X-rays, enabling a wide range of simultaneous multi-wavelength observations. The Canadian Space Agency is supplying the photon-counting detectors and electronics for UVIT. These have been calibrated at the University of Calgary (U of C) and are undergoing final integration with the spacecraft. UVIT will provide flux calibrated images of the sky at a spatial resolution of 1-2 arcsec. The results of the characterization of the UVIT detectors using the UV vacuum laboratory at University of Calgary will be described.

135.08 – **In-flight Performance of the Water Vapor Monitor Onboard the SOFIA Observatory**

Thomas L. Roellig[1], L. Yuen[2], D. Sisson[2], R. Hang[3]

[1]*NASA Ames Research Center,* [2]*TechnoScience Corporation,* [3]*NASA Dryden Flight Research Center.*

9:00 AM - 6:30 PM

NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) airborne observatory flies in a modified B747-SP aircraft in the lower stratosphere above more than 99.9% of the Earth's water vapor. As low as this residual water vapor is, it will still affect SOFIA's infrared and sub-millimeter astronomical observations. As a result, a heterodyne instrument has been developed to observe the strength and shape of the 183GHz rotational line of water, allowing measurements of the integrated water vapor overburden in flight. In order to be useful in correcting the astronomical signals, the required measured precipitable water vapor accuracy must be 2 microns or better, 3 sigma, and measured at least once a minute. The Water Vapor Monitor has flown 22 times during the SOFIA Early Science shared-risk period. The instrument water vapor overburden data obtained were then compared with concurrent data from GOES-V satellites to perform a preliminary calibration of the measurements. This presentation will cover the results of these flights. The final flight calibration necessary to reach the required accuracy will await subsequent flights following the SOFIA observatory upgrade that is taking place during the spring and summer of 2012.

135.09 – **Geometric Calibration of the H-4RG Detector**

Steven Howard Pravdo[1], S. Shaklan[1], B. Dorland[2], R. Dudik[2]

[1]*Caltech, JPL,* [2]*USNO.*

9:00 AM - 6:30 PM

A Hawaii-4RG detector was developed for the Joint Milli-Arcsecond Pathfinder Survey (JMAPS). JMAPS was to have been an all-sky astrometric survey designed to observe stars in the range mI = 0-14, with the capability to observe QSOs as faint as mI = 16. Stars with mI = 0-12 and quasars out to ~16 mag were to be observed with single measurement precision < 5 mas, with final mission accuracies after 72 observations of < 1 mas. For the JMAPS plate scale the single measurement precision corresponded to ~0.01 pixel. This large dynamic range was enabled by multiple "guide windows (GWs)" that read out 15 x 15 pixel squares on the focal plane at far higher rates than the other pixels, thereby forestalling saturation. The increase in dynamic range is as large as ~1000, equal to the ratio of the readout time in the full frame versus that of the GWs. The space mission has been cancelled. However, laboratory tests of the geometrical and projected astrometric accuracy of the camera were started and continue. The H-4RG is a 4K x 4K CMOS device with 10-micron pitch developed by Teledyne Imaging Systems, Inc. under contract to the Navy. We report preliminary data that show features in the apparent pixel locations in the full frame, and an investigation of the effects of the GWs on pixel locations. Copyright JPL.

135.1 – **Affordable and High-heritage SMEX Spacecraft Solutions**

Greg Lee[1], J. Rickey[1], A. Lo[1], K. Griffin[1], M. Riesco[2]

[1]*Northrop Grumman,* [2]*Sierra Nevada Corporation.*

9:00 AM - 6:30 PM

Given NASA's Astrophysics budget constraints in the next several years, the Small Explorers (SMEX) Program is becoming an even more crucial aspect of space-borne scientific investigations as it provides frequent mission opportunities at modest mission cost cap. As such, SMEX missions require inexpensive yet reliable spacecraft to achieve the science objectives. To meet the mission needs of low-cost, reliable spacecraft, Northrop Grumman (NG) Corporation and Sierra Nevada Corporation (SNC) have teamed to provide ideal SMEX bus solutions, combining SNC's low cost, small bus from the current ORBCOMM 2 (OG-2) production line and NG's world-class expertise and over half a century of experience in space science mission architecture, systems engineering and space vehicle integration. The OG-2 spacecraft bus is 3-axis stabilized, capable of providing modest pointing capabilities and able to accommodate a wide range of SMEX-class instruments; with slight modifications, the performance is greatly enhanced in pointing and payload accommodation capabilities. Our combination of NG's expertise and SNC's low cost, OG-2 based spacecraft provides our science partners with the depth and skill set needed during all phases of SMEX investigation development from mission inception to flight element development, successful launch, and high-performance science operations.

135.12 – **AstroDrizzle: A Guide to Creating HST Mosaics**

Jennifer R. Mack[1], W. Hack[1], STScI AstroDrizzle Team

[1]*STScI.*

9:00 AM - 6:30 PM

AstroDrizzle is a new tool for combining HST images and removing geometric distortion. It is part of a suite of tasks in the new software package Drizzlepac, now available from STScI. Using these new tools, we demonstrate a strategy for creating mosaics from HST images when very little overlap exists between tiles. Using the WFC3 ERS observations of M83, we describe how to use 'astrodrizzle' in combination with 'tweakreg' and 'tweakback' to improve the astrometric alignment between tiles to better than 0.1 pixel accuracy. Once this is achieved, the entire mosaic may be combined in a single call to 'astrodrizzle' to create a clean composite image.

135.13 – **AstroDrizzle: Aligning Images From Multiple Instruments**

Roberto J. Avila[1], W. J. Hack[1], STScI AstroDrizzle Team

[1]*Space Telescope Science Institute.*

9:00 AM - 6:30 PM

AstroDrizzle is new software for aligning and drizzling Hubble Space Telescope images. It is a substantial improvement on the current MultiDrizzle with a particular enhancement on the handling of astrometry. This software is part of the new STSDAS package DrizzlePac, a suite of tasks that will replace the STSDAS Dither package.

We present an example where we use the Tweakreg task to align images from multiple HST instruments: WFPC2, ACS/WFC, WFC3/UVIS, WFC3/IR. Even though each image has different characteristics (plate

scales,distortion,rotations,epochs,etc.), Tweakreg makes it easy to align them to within 0.1 pixel accuracy. This type of work will be of benefit to the many archival users who analyse datasets taken with different HST instruments.

135.14 – **AstroDrizzle: A Photometric Performance Study**

Leonardo Ubeda[1], STScI AstroDrizzle Team

[1]*Space Telescope Science Institute.*

9:00 AM - 6:30 PM

AstroDrizzle is a new software task for correcting geometric distortion, aligning, and drizzling Hubble Space Telescope images.

It retains the same Drizzle algorithmic base as its predecessor, MultiDrizzle, but provides substantial improvement in the handling of

astrometric information. This software is part of the new STSDAS package DrizzlePac, a suite of tasks that will replace the STSDAS Dither package. As part of the extensive testing conducted at STScI, we present a photometric study on ACS/WFC images that shows the reliability and accurate performance of the new software.

135.15 – **AstroDrizzle: More than a New MultiDrizzle**

Warren J. Hack[1], N. Dencheva[1], A. S. Fruchter[1], A. Armstrong[1], R. Avila[1], S. Baggett[1], E. Bray[1], M. Droettboom[1], M. Dulude[1], S. Gonzaga[1], N. A. Grogin[1], V. Kozhurina-Platais[1], R. A. Lucas[1], J. Mack[1], J. MacKenty[1], L. Petro[1], N. Pirzkal[1], A. Rajan[1], L. J. Smith[1], C. Sontag[1], L. Ubeda[1]

[1]*STScI.*

9:00 AM - 6:30 PM

AstroDrizzle is new software for aligning and drizzling Hubble Space Telescope images. It is a substantial improvement on the current MultiDrizzle with a particular enhancement on the handling of astrometry. This software is part of the new STSDAS package DrizzlePac, a suite of tasks that will replace the STSDAS Dither package. This package allows the user to do a lot more than simply combine their HST images with high photometric and astrometric fidelity. We present examples based on HST images that show how the tasks in this package now provide a new paradigm for working with the world coordinate system of these images, for aligning the images and for combining them with AstroDrizzle to produce the best possible HST science. The details of the combined images generated by AstroDrizzle are also discussed to illustrate how the provenance of the final product now gets maintained.

135.16 – **AstroDrizzle: Utilizing New CALACS Products**

Ray A. Lucas[1], STScI AstroDrizzle Team, ACS Team

[1]*STScI.*

9:00 AM - 6:30 PM

Recent improvements and additions to the standard ACS data calibration pipeline have made for better data in several ways: a robust and widely-applicable de-striping algorithm, the pixel-based correction of CTE trails, and better bias shift correction, among other things. These are particularly important improvements for post-SM4 ACS data. Effects such as CTE trails and striping are either more prominent or new in more recent data after the additional years of on-orbit radiation damage and the installation of the new CCD Electronics Box Replacement (CEB-R) with its SIDECAR ASIC (Application-Specific Integrated Circuit) circuitry. The latter imposes a striping pattern in all post-SM4 ACS/WFC data. Finally, the AstroDrizzle software from the new DrizzlePac software package for aligning, CR-cleaning, and combining images is used. We present some newly re-processed post-SM4 ACS/WFC data as example of these improvements.

135.17 – **Visualizing 3-D Datasets In The New SAOImage DS9 V7.0**

Tracy L. Beck[1], B. Joye[2], A. Conti[1]

[1]*Space Telescope Science Institute,* [2]*Harvard - Center for Astrophysics.*

9:00 AM - 6:30 PM

To expand current options available for visualization of complex 3-D astronomical datasets, we report on the development of a new module for the popular Astronomical data visualization tool, SAOImage DS9. The new module, "Frame 3-D", allows users to visualize datacubes rotated in elevation and azimuth angles, at perspectives beyond the standard 2-D x / y axis view. The functionalities of the new 3-D module in DS9 are highlighted, and we demonstrate the usage of the new visualization capabilities using 3-D integral field spectroscopic data. We also briefly discuss analysis tasks that can be developed to work with the expanded 3-D macro capabilities. DS9 v. 7.0 will be released to the astronomical community in April 2012. SAOImage DS9 development has been made possible by funding from the Chandra X-ray Science Center, the High Energy Astrophysics Science Archive Center, and the JWST Mission office at the Space Telescope Science Institute.

135.18 – **On the Significance of Absorption Features in HST/COS Data**

Brian A. Keeney[1], C. W. Danforth[1], J. T. Stocke[1], J. C. Green[1]

[1]*Univ. of Colorado.*

9:00 AM - 6:30 PM

We present empirical scaling relations for the significance of absorption features detected in medium resolution, far-UV spectra obtained with the Cosmic Origins Spectrograph (COS) aboard the *Hubble Space Telescope*. These relations properly account for both the extended wings of the on-orbit COS line spread function and the non-Poissonian noise properties of the data, which we characterize for the first time. This non-Poissonian noise has a profound effect on the detectability of broad, shallow absorption features, such as Lyα and metal-line absorption associated with the warm-hot intergalactic medium. Our empirical scalings predict limiting equivalent widths that deviate from the exact solutions by < 5% when the wavelength and Doppler parameter are in the ranges 1150-1750 A and b > 10 km/s.

136 – Space Telescopes & Instrumentation

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

136.01 – **Updates to the Performance of the Space Telescope Imaging Spectrograph**

John H. Debes[1], A. Aloisi[1], R. C. Bohlin[1], K. A. Bostrom[1], C. Cox[1], R. Diaz[1], J. Duval[1], J. Ely[1], E. Mason[1], R. Osten[1], C. Proffitt[1], P. Sonnentrucker[1], M. A. Wolfe[1]

[1]*Space Telescope Science institute.*

9:00 AM - 6:30 PM

STIS remains a significantly used instrument on the Hubble Space Telescope, accounting for the most prime orbits (22%) after WFC3 in Cycle 19. We continue to monitor and improve upon the performance of the instrument since the revival of STIS in 2009, with two cycles of monitoring complete since Servicing Mission 4 (SM4). In this poster, we present updates to that monitoring. For each of the detectors on STIS, we report on the latest status of full field sensitivities, dark rates, time dependent spectroscopic sensitivities, and geometric distortion solutions.

136.02 – **COS Acquisition Strategies**

Brian Andrew York[1], A. Aloisi[1], S. Penton[1], C. Proffitt[1], D. Sahnow[1], P. Sonnentrucker[1]

[1]*Space Telescope Science Institute.*

9:00 AM - 6:30 PM

With its small aperture and dispersed-light target acquisitions, COS presents unique challenges in successfully acquiring targets for science. We provide a number of tips for optimizing a COS target acquisition, along with potential pitfalls which might compromise the resulting science.

136.03 – **A Fresh Start for the COS FUV Detector**

Cristina M. Oliveira[1], A. Aloisi[1], J. Ely[1], G. Kriss[1], D. Massa[1], R. Osten[1], S. Osterman[2], S. Penton[1], C. Proffitt[1], D. Sahnow[1]

[1]*Space Telescope Science Institute,* [2]*University of Colorado.*

9:00 AM - 6:30 PM

To forestall possible loss in recorded flux due to charge depletion (or "gain sag"), the location of spectra obtained with the far ultraviolet (FUV) detector of the Cosmic Origins Spectrograph (COS) on HST will be moved to a different position on the detector, i.e., a new lifetime position, in the summer of 2012.

In order to maximize science quality over the next five years, a study of the impact of a new lifetime position on the performance of the COS FUV detector and optics was carried out.

The following parameters were considered in this study: spectral resolution, projected lifetime, overall flat-field characteristics, impact of new lifetime position on target acquisition, aperture mechanism, and wavelength calibration lamp, and the effect of the next lifetime position on subsequent positions. Here we report on the conclusions of this study; recommendations for the location of the next lifetime position as well as for the location of future lifetime positions are also discussed.

136.04 – **Recent Trends in the COS FUV Time Dependent Sensitivity**

K. Azalee Bostroem[1], R. Osten[1], O. Lupie[2], D. Massa[1], A. Aloisi[1], C. Proffitt[1]

[1]*Space Telescope Science Institute,* [2]*Goddard Space Flight Center.*

9:00 AM - 6:30 PM

Following the installation of the Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope (HST) during Servicing Mission 4 in May 2009, the sensitivity of the COS far ultraviolet (FUV) detector was observed to be declining much faster than predicted. The initial sensitivity declines were wavelength dependent, with worse declines at longer FUV wavelengths. From March 2010 to March 2011, the rate of the sensitivity decline became much smaller and was largely wavelength independent. In early 2011 the rate of sensitivity decline increased slightly and a similar but weaker wavelength dependence returned. Another increase in the rate of sensitivity decline occurred in October 2011. These wavelength dependent trends are consistent with degradation of the quantum efficiency of the FUV CsI photocathode on the front of the microchannel plate of the FUV windowless detector due to environmental factors encountered in flight. The degradation is dominated at early times by an outgassing product (likely water vapor) and at later times by another factor with longer timescales, likely highly reactive Atomic Oxygen in the residual Earth's atmosphere at HST altitude. Degradation by Atomic Oxygen predicts a steepening of the rate of the COS FUV sensitivity decline as the Earth's atmospheric density increases with the solar cycle approaching maximum. We describe the latest results of our COS FUV sensitivity monitoring program, their correlation with the solar cycle activity, updates of pipeline reference files, and expectations for users in Cycle 20.

136.05 – **Strategies For The Mitigation Of Gain Sag In The Cos Fuv Detectors**

Justin Ely[1], A. Aloisi[1], K. Bostroem[1], P. Hodge[1], G. Kriss[1], D. Massa[1], C. Oliveira[1],

R. Osten[1], S. Penton[1], C. Proffitt[2], D. Sahnow[1], B. York[1]
[1]STScI, [2]STScI/CSC.
9:00 AM - 6:30 PM

The far ultraviolet (FUV) channel on the Cosmic Origins Spectrograph (COS) suffers localized flux loss due to gain sag from continued exposure to light. Because of the non-uniformity of observed spectra falling on the detector, gain sag holes in extracted spectra first appear in the most illuminated portions of the detector, those affected by bright airglow lines, and will eventually impact large regions of the continuum as well. In order to preserve the data quality and extend the operational lifetime of COS, strategies have been implemented which impact nearly every aspect of COS operations. These include changes to default observing sequences, improved monitoring, new calibration procedures, changes to detector electronics, and a complete relocation of the illuminated portion of the detector.

136.06 – **Gapless And Low Far-uv Astigmatism Mode For Cos G140l**
Keith Redwine[1], B. Fleming[1], S. R. McCandliss[1], S. Osterman[2], J. C. Howk[3], W. Zheng[1], S. F. Anderson[4], B. T. Gaensicke[5], K. France[2]
[1]Johns Hopkins University, [2]University of Colorado, [3]University of Notre Dame, [4]University of Washington, [5]University of Warwick, United Kingdom.
9:00 AM - 6:30 PM

The demonstrated sensitivity of COS G140L mode to wavelengths below 1150 A has opened a new window to the universe in a bandpass hitherto inaccessible to Hubble, which has enabled a number of interesting science investigations. To more fully exploit this anticipated but unplanned for capability, in cycle 19 we successfully proposed to establish a new observing mode, wherein CENWAVE will be set to 800 A, thereby providing contiguous wavelength coverage from 900 to 1850 A on the Segment A detector of COS. This has three principal advantages: 1) an ~ 2 times lower background from reduced astigmatism at the short wavelength end where the effective area is lowest, which will boost the S/N of background limited observations; 2) contiguous spectral coverage on a single detector segment, which will simplify tracking of flux, wavelength and flat-field calibrations; and 3) a more efficient use of observing time for programs requiring the full far-UV wavelength coverage by eliminating the need for a grating change. Preliminary observations with this new mode are expected in April of 2012. They require two basic adjustments, a slight rotation of the grating wheel followed by a focus sweep. Here we describe our preparations for the flux and wavelength calibration of this new mode, which will utilize archival spectra of AV234 previously acquired by FUSE and HST FOS. AV 243 was selected for its relatively high density of narrow molecular hydrogen spectral bands, as well as its brightness suitable for a sufficiently high signal-to-noise ratio while remaining below for the Bright Object Protection limit for COS. These data will guide our analysis of the best focus position, spectral extraction windows, and an estimate for the effective area for the CENWAVE 800 mode of COS G140L mode.

136.07 – **Medium Resolution "EUV" Observing With HST+COS In Cycle 20**
Steven V. Penton[1], J. Duval[2], K. France[3], D. Massa[4], C. Oliveira[2], S. Osterman[1], P. Sonnentrucker[2]
[1]Univ. of Colorado, [2]Space Telescope Science Institute, [3]University of Colorado, [4]Space Science Telescope Institute.
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 G140L/1280 and the Cycle 19 available G130M central wavelengths (1055 and 1096) that sample below 1150Å are low-resolution (R < 5,000). In HST Cycle 20, the resolution of the G130M/1055 and 1096 modes should be more than doubled by changing the focus positions of the internal mechanism to that used for the new G130M/1222 setting (1060-1368Å, R > 10,000). Here we present the current calibration status of the COS G130M/1055, 1096, and 1222 central wavelength settings with an emphasis on Cycle 20 observing implications over the combined spectral range of 900--1368Å.

136.08 – **Pixel-based CTE Correction of ACS/WFC: Dark Reference Files**
Sara Ogaz[1], J. Anderson[1], N. Grogin[1], P. Lim[1]
[1]Space Telescope Science Institute.
9:00 AM - 6:30 PM

In the spring of 2012 a new version of CALACS, the data pipeline for the Advanced Camera for Surveys (ACS) on the Hubble Space Telescope, was released. One of the major improvements in the new CALACS is the incorporation of the algorithm created by Anderson and Bedin (2010) to correct the charge transfer efficiency (CTE) losses in the Wide Field Channel (WFC). This algorithm is a pixel specific correction that is applied as one of the first steps in CALACS, before the subtraction of the dark reference file. In order to properly reduce any raw science images it was necessary to correct all the WFC dark reference files used in CALACS for CTE, about 1,600 files. These corrected dark files are an important part of CALACS and demonstrate the effectiveness of the CTE correction.

136.09 – **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 Hubble Space Telescope's Wide Field Camera 3 continues to perform at or better than its specifications. The team at STScI provides both user support and instrument calibration with several major improvements in calibration over the past year. This poster describes: (1) our continuing analysis and recommendations for mitigation of changes in the CTE of the CCD detectors, (2) improvements to key calibrations for detector flat fields, photometric zero points, and slitless sectroscopic modes, (3) calibration of the stability and linearity of the infrared detector, (4) the availability of pixel history tracking to support identification and partial correction of image persistence in infrared images, and (5) results from our initial investigations of using spatial scan mode to enhance differential photometry and astrometry of bright sources.

136.1 – **A Pixel-based Cte Correction For Hst's Wfc3/uvis**
Jay Anderson[1], WFC3 team
[1]STScI.
9:00 AM - 6:30 PM

We report on the effort to construct a pixel-based model for CTE (charge-transfer efficiency) in WFC3's UVIS detector, using an approach very similar to our successful ACS/WFC model. We find that the general model works well, but the distribution of charge traps and release times is naturally somewhat different. The model allows us to evaluate absolute CTE losses in different observing scenarios, which will help users optimize their observing strategies. The model also allows us to reconstruct the original pixel distribution for any given observation. We will evaluate the quality of reconstruction in various science scenarios.

136.11 – **Augmenting The HST Pure Parallel Observations**
Alan Patterson[1], G. Soutchkova[2], W. Workman[1]
[1]CSC/STScI, [2]STScI.
9:00 AM - 6:30 PM

Pure Parallel (PP) programs, designated GO/PAR, are a subgroup of General Observer (GO) programs. PP execute simultaneously with prime GO observations to which they are "attached". The PP observations can be performed with ACS/WFC, WFC3/UVIS or WFC3/IR and can be attached only to GO visits in which the instruments are either COS or STIS. The

current HST Parallel Observation Processing System (POPS) was introduced after the Servicing Mission 4. It increased the HST productivity by ~10% in terms of the utilization of HST prime orbits and was highly appreciated by the HST observers, allowing them to design efficient, multi-orbit survey projects for collecting large amounts of data on identifiable targets.

The results of the WFC3 Infrared Spectroscopic Parallel Survey (WISP), Hubble Infrared Pure Parallel Imaging Extragalactic Survey (HIPPIES), and The Brightest-of-Reionizing Galaxies Pure Parallel Survey (BoRG) exemplify this benefit. In Cycle 19, however, the full advantage of GO/PARs came under risk. Whereas each of the previous cycles provided over one million seconds of exposure time for PP, in Cycle 19 that number reduced to 680,000 seconds. This dramatic decline occurred because of fundamental changes in the construction of COS prime observations. To preserve the science output of PP, the PP Working Group was tasked to find a way to recover the lost time and maximize the total time available for PP observing. The solution was to expand the definition of a PP opportunity to allow PP exposures to span one or more primary exposure readouts. So starting in HST Cycle 20, PP opportunities will no longer be limited to GO visits with a single uninterrupted exposure in an orbit. The resulting enhancements in HST Cycle 20 to the PP opportunity identification and matching process are expected to restore the PP time to previously achieved and possibly even greater levels.

136.12 – **Status of the JWST Science Instrument Module**
Matthew A. Greenhouse[1], J. Dunn[1], S. Lambros[1], R. Lundquist[1], B. Rauscher[1], M. Voyton[1]
[1]NASA's GSFC.
9:00 AM - 6:30 PM

The Integrated Science Instrument Module (ISIM) of the James Webb Space Telescope (JWST) is the science instrument payload of the JWST. It is a 1.4 metric ton element of the JWST space vehicle that consists of four science instruments and nine instrument support systems. The flight ISIM began integration and test during 2011. This presentation will review the current status of the ISIM system and its science instrumentation.

136.13 – **WFIRST Needs 3 Microns**
Edward L. Wright[1]
[1]UC, Los Angeles.
9:00 AM - 6:30 PM

The Wide-Field InfraRed Survey Telescope (WFIRST) should work out to 4 microns instead of the current 2 or 2.5 micron cutoff for maximum science return. The signal-to-noise ratio

on distant faint galaxies and quasars is maximized in the zodiacal light minimum at 3-4 microns. The SNR for measuring shapes for weak lensing also depends on PSF size relative to the galaxy size, but for an exponential scale length of 0.1" at z=2 (850 pc), the optimum wavelength is in the 2-3 micron range. While the PSF of a 1.3 m telescope at 3 microns has a FWHM of 0.5", this is still smaller than the seeing-limited PSF of LSST which plans to do weak lensing. The scatter in supernova Hubble diagrams is much lower for data taken in the rest frame near-infrared (0.11 mag) compared to rest-frame optical (0.18 mag), so at redshift z=2 one desires photometry at 3.75 microns. So each supernova observed in the rest-frame near-IR is worth 2-3 supernova observed in the rest frame optical. Microlensing is looking at zero redshift stars, and would use a filter to isolate an optimal bandpass, so it would be no worse with a longer detector cutoff wavelength. Slitless spectroscopy to measure Baryon Acoustic Oscillations will concentrate on redshifted H-alpha, and use a filter to select the desired redshift range, so a longer cutoff wavelength just gives more flexibility in targeting the

redshift range. Thus the performance of WFIRST with a long cutoff wavelength is either substantially improved (for SNe and the high latitude survey), slightly improved (for weak lensing) or not hurt (for microlensing and BAO), and the overlap with the capabilities

of Euclid is much reduced. NASA support for my participation on the WFIRST SDT is acknowledged.

136.14 – **Status Of The Fortis Rocket-borne Far-uv Spectro-telescope**

Brian Fleming[1], S. R. McCandliss[1], K. Redwine[1], M. Kaiser[1], P. D. Feldman[1], J. Kruk[2], A. S. Kutyrev[2], M. J. Li[2], S. H. Moseley[2], D. A. Rapchun[3], O. Siegmund[4], J. Vallerga[4], A. Martin[4]

[1]*Johns Hopkins University,* [2]*NASA Goddard Space Flight Center,* [3]*Global Science and Technology,* [4]*Sensor Sciences.*

9:00 AM - 6:30 PM

The Far-ultraviolet Off Rowland-circle Telescope for Imaging and Spectroscopy (FORTIS) is a rocket-borne multi-object spectro-telescope designed to investigate Lyman alpha (Lya) escape from nearby star-forming galaxies and to quantify its relationship to the local gas-to-dust ratio (Fleming et al. 2011). In addition to a novel "two-bounce" optical configuration, FORTIS will feature the first space application of a NASA/Goddard designed JWST/NIRSPEC prototype microshutter array. This enables spectral multiplexing in the 900 - 1800 Angstrom bandpass over a 30' x 30' field of view with "on-the-fly" targeting. We report on the preparation of the instrument for launch and the results of end-to-end testing of the assembled payload. Special emphasis is given to the performance of the microshutter array and custom designed autonomous targeting system, the measured optical performances, and the overall instrument effective area.

136.15 – **Progress in Soft X-ray Polarimetry**

Herman L. Marshall[1], N. Schulz[1], R. Heilmann[1], K. Kochanski[1]

[1]*MIT.*

9:00 AM - 6:30 PM

We developed an instrument design capable of measuring linear X-ray polarization over a broad-band using conventional spectroscopic optics. A set of multilayer-coated flats reflects the dispersed X-rays to the instrument detectors. The intensity variation with position angle is measured to determine three Stokes parameters: I, Q, and U -- all as a function of energy. By laterally grading the multilayer optics and matching the dispersion of the gratings, one may take advantage of high multilayer reflectivities and achieve modulation factors >50% over the entire 0.2 to 0.8 keV band. This instrument could be used in a small orbiting mission or the approach could be used on a large dispersive spectrometric facility. We present progress on laboratory work to demonstrate the capabilities of key components.

We thank the MIT Kavli Institute and the NASA Astrophysics Research and Analysis program for funding.

136.16 – **Recent Advances In Cryogenic Monolithic Millimeter-wave Integrated Circuit (MMIC) Low Noise Amplifiers For Astrophysical Observations**

Lorene Samoska[1], S. Church[2], K. Cleary[3], T. Gaier[1], R. Gawande[3], P. Kangaslahti[1], C. Lawrence[1], A. Readhead[3], R. Reeves[3], M. Seiffert[1], M. Sieth[2], M. Varonen[1], P. Voll[2]

[1]*Jet Propulsion Laboratory,* [2]*Stanford University,* [3]*California Institute of Technology.*

9:00 AM - 6:30 PM

In this work, we discuss advances in high electron mobility transistor (HEMT) low noise amplifier (LNA) monolithic millimeter-wave integrated circuits (MMICs) for use as front end amplifiers in ultra-low noise receivers. Applications include focal plane arrays for studying the polarization of the cosmic microwave background radiation and foreground separation, receiver arrays for molecular spectroscopy, and high redshift CO surveys for probing the epoch of reionization. Recent results and a summary of best indium phosphide (InP) low noise amplifier data will be presented.

Cryogenic MMIC LNAs using state-of-the-art InP technology have achieved record performance, and have advantages over other detectors in the 30-300 GHz range. InP MMIC LNAs operate at room temperature and may achieve near-optimum performance at 20K, a temperature readily achieved with modern cryo-coolers. In addition, wide-bandwidth LNAs are suitable for heterodyne applications as well as direct detector applications. Recent results include Ka-band MMICs with 15K noise temperature performance, and Q-Band MMICs with on-wafer measured cryogenic noise of 12K at 38 GHz. In addition, W-Band amplifiers with 25K noise temperature at 95 GHz will be presented, as well as wide-band LNAs with noise temperature below 45K up to 116 GHz. At higher frequencies, we will discuss progress on MMIC LNAs and receiver modules in G-Band (140-220 GHz), where our group has achieved less than 60K receiver noise temperature at 166 GHz. We will address extending the high performance of these MMIC LNAs to even higher frequencies for spectroscopic surveys, and make projections on future performance given current trends. These MMIC amplifiers can play a key role in future ground-based and space-based instruments for astrophysical observations.

136.17 – **Materials Testing for a Lunar Radio Telescope with the LUNAR Simulant Thermal-Vacuum Chamber**

Kristina Davis[1], L. Kruger[1], C. Yarrish[1], J. Burns[1]

[1]*University of Colorado.*

9:00 AM - 6:30 PM

The LUNAR (Lunar University Network for Astrophysics Research) team has proposed a revolutionary new telescope design that will make observations from the lunar farside. In order to withstand the harsh conditions on the lunar surface, the telescope must be extremely durable, and lightweight to save on launch costs. The LUNAR Radio Array will thus be made of long Kapton arms to that hold the photon-collecting dipoles. The LUNAR Simulation Laboratory team at the University of Colorado has designed and constructed a vacuum chamber to measure the durability of these antennae materials, as well as test deployment scenarios. The chamber replicates the vacuum, thermal, and UV radiation environment on the lunar surface. Additionally, the chamber houses a lunar simulant bed upon which the experiments are performed. The simulant temperature is controlled by a thermal plate underneath the bed. In the early summer of 2012, the team will run an experiment within the chamber to test the thermal properties of a sheet of Kapton film that has been coated with copper to simulate the dipole array. Several thermocouples will be placed on top of the film to monitor the temperature swings between daytime and nighttime conditions. A video camera will monitor the thermal expansion and contraction of the film. This experiment will follow up on previous testing where the film was placed directly on the thermal plate. The team will determine the difference in temperature transition time since the contact area between a solid plate and a bed of particulates is significant.This will be the pilot experiment that the team has done on top of lunar simulant. The team will be testing the thermal properties of the simulant itself, as well as testing the filtration system that guards the vacuum pumps against contamination. Subsequent experiments will use this data as a baseline.

137 – CSWA: Introduction to Astronomical Bullying

Town Hall – Ballroom C, Dena'ina Center – 6/11/2012 12:45:00 PM to 6/11/2012 1:45:00 PM

Unprofessional behavior is not limited to gender discrimination and sexual harassment. There are cases when â€œsomething is just not rightâ€ in the workplace, which may involve no sexual overtones whatsoever. One such example is Astronomical Bullying, which can have some characteristics in common with childhood bullying. It is not limited to women. It can involve teasing or taunting. It can be overt or covert. It can be physically or psychologically threatening. It can come from a supervisor or a collaborator. It can involve spreading rumors about your qualifications or abilities as a scientist. The stress associated with a bullying situation can affect your work and your health. You may even feel that your future career is in jeopardy. The CSWA Town Hall at the Anchorage AAS meeting will introduce the concept of Astronomical Bullying. The Town Hall will include at least 30 minutes for discussion and answering questions from the audience.

138 – The NASA Kepler Mission Town Hall: 2012 and Beyond

Town Hall – Ballroom A, Dena'ina Center – 6/11/2012 6:30:00 PM to 6/11/2012 8:00:00 PM

The NASA Kepler mission has recently been granted a mission extension by the Astrophysics Senior Review process.This Town Hall will present the Kepler project plans for the extended mission. These include significant changes in the data release policy,availability of new project products, avenues for community involvement via the Kepler Participating Scientist Program and Guest Observer program, as well as the role of the MAST and NexSci archives. Please come join us for this town hall reception, meet the Kepler team, and learn about the future mission plans for both planet discovery and astrophysics using Kepler data.

200 – CME

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/11/2012 6:30:00 PM

200.01 – **Relating CME Shock Front Observations to their In-Situ Signatures**

Phillip Hess[1], J. Zhang[1]

[1]*George Mason University.*

9:00 AM - 6:30 PM

When a fast Coronal Mass Ejection strikes the Earth, it will often be preceded by a shock front. By studying the propagation of these shock fronts in the Heliosphere and the evolution of the standoff distance between the ejecta front and the shock front using white light observations from the SOHO and STEREO Spacecrafts

improvements can be made to predictions of shock and CME arrival at the Earth and to the theoretical modeling of how these shocks are driven. These results are further improved by comparing shock and CME propagation as measured in the Heliosphere to in-situ solar wind signatures at 1 AU obtained from the ACE satellite. For this study, multiple events have been tracked through the Heliosphere and linked with their arrival at the Earth. Of the events presented, the April 03, 2010 CME shows a particularly strong correlation in both arrival time and standoff distance as measured from observations and in-situ signatures showing that information obtained from white light images can be used to predict the arrival of shocks at the Earth, which has important implications for space weather forecasting.

200.02 – **Mass Constraints of Hot and Cold Coronal Mass Ejection Plasmas Observed in EUV and X-ray**

Jin-Yi Lee[1], J. C. Raymond[2], K. K. Reeves[2], Y. Moon[1]
[1]*Kyung Hee University, Korea, Republic of,* [2]*Harvard-Smithsonian, CfA.*
9:00 AM - 6:30 PM

Hinode/XRT has observed coronal mass ejections (CMEs) since it launched on Sep. 2006. Observing programs of Hinode/XRT, called 'CME watch', perform several binned observations to obtain large FOV observations with long exposure time that allows the detection of faint CME plasmas in high temperatures. Using those observations, we determine the upper limit to the mass of hot CME plasma using emission measure by assuming the observed plasma structure. In some events, an associated prominence eruption and CME plasma were observed in EUV observations as absorption or emission features. The absorption feature provides the lower limit to the cold mass while the emission feature provides the upper limit to the mass of observed CME plasma in X-ray and EUV passbands. In addition, some events were observed by coronagraph observations (SOHO/LASCO, STEREO/COR1) that allow the determination of total CME mass. However, some events were not observed by the coronagraphs possibly because of low density of the CME plasma. We present the mass constraints of CME plasma and associated prominence as determined by emission and absorption in EUV and X-ray passbands, then compare this mass to the total CME mass as derived from coronagraphs.

200.03 – **Alternating Twist in an Erupting Prominence**

William T. Thompson[1]
[1]*Adnet Systems, Inc..*
9:00 AM - 6:30 PM

Updated analysis of an erupting prominence on 6-7 December 2010 shows the presence of alternating regions of twist along the filament channel, as found using triangulation with STEREO Ahead and Behind when the two spacecraft were close to 180 degrees separation. Earlier analysis suggested that the erupting prominence changed helicity signs, as expressed through the twist, just prior to eruption. It is now recognized that different parts of the prominence have different twists, and the relative importance of these different segments changes with time. The two parts of the overall prominence structure with positive twist erupt, with the left branch erupting on 6 December, and the right branch erupting twelve hours later on the following day. In between these two erupting branches is a non-erupting segment with negative twist.

200.04 – **Comparison of Prominence Structures with Instances of Flux Rope CMEs in STEREO Data**

Amy Rager[1], B. J. Thompson[2], S. K. Antiochos[2], A. Thernisien[3], W. T. Thompson[4]
[1]*NASA GSFC/CUA,* [2]*NASA GSFC,* [3]*GMU,* [4]*NASA GSFC/ADNET.*
9:00 AM - 6:30 PM

STEREO A and B CME data have been visually searched for instances of flux ropes, signified by a concave outward cavity feature in the COR1 coronagraph. The flux rope events selected were observed by both spacecraft, and also had visible prominences in both EUVI-A and EUVI-B. The appearance of a flux rope was compared to the angle of the inferred magnetic neutral line of the CME to discover if a relationship existed. The GCS CME flux rope model was fit to the COR1 data, allowing for a clearer representation of the flux rope structure to compare with the magnetic neutral line.

200.05 – **The CORIMP CME Catalogue: Automatically Detecting and Tracking CMEs in Coronagraph Data**

Jason Byrne[1], H. Morgan[2], S. R. Habbal[1]
[1]*Institute for Astronomy,* [2]*University of Aberystwyth, United Kingdom.*
9:00 AM - 6:30 PM

Studying CMEs in coronagraph data can be challenging due to their diffuse structure and transient nature, and user-specific biases may be introduced through visual inspection of the images. The large amount of data available from the SOHO and STEREO missions also makes manual cataloguing of CMEs tedious, and so a robust method of detection and analysis is required. This has led to the development of automated CME detection and cataloguing packages such as CACTus, SEEDS and ARTEMIS. Here we present the development of the CORIMP (coronal image processing) Catalogue: a new, automated, multiscale, CME detection and tracking catalogue, that overcomes many of the drawbacks of current catalogues. It works by first employing a dynamic CME separation technique to remove the static background, and then characterizing CME structure via a multiscale edge-detection algorithm. The detections are chained through time to determine the CME kinematics and morphological changes as it propagates across the plane-of-sky. The effectiveness of the method is demonstrated by its application to a selection of SOHO/LASCO and STEREO/SECCHI images, as well as to synthetic coronagraph images created from a model corona with a variety of CMEs. These algorithms are being applied to the whole LASCO and SECCHI datasets, and a CORIMP catalogue of results will soon be available to the community.

200 – CME

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

200 – CME

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

200 – CME

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

201 – Solar & Stellar

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

201.01 – **The US 2017 Total Solar Eclipse Workshops**

Martina B. Arndt[1], S. R. Habbal[2], Solar Wind Sherpas
[1]*Bridgewater State University,* [2]*Institute for Astronomy.*
9:00 AM - 6:30 PM

In preparation for the Total Solar Eclipse that will span across the United States in 2017, multiple eclipse workshops are being planned to bring together professional and amateur researchers, educators, and imagers. Our ultimate goal with these workshops is to maximize the amount and quality of data we can collect during the eclipse as well as to leverage this exciting event to educate and inspire people of all ages. Part of the workshops will be dedicated to discussing the science that can be learned from observing total solar eclipses, and part of the workshops will be dedicated to strategizing about how to mobilize and prepare communities in the path of totality. In this poster, we will share our preliminary results from the inaugural workshop in Maryland, April 2012.

201.02 – **High-resolution Solar Imaging with a Photon Sieve**

Joseph M. Davila[1]
[1]*Goddard Space Flight Center.*
9:00 AM - 6:30 PM

Dissipation in the solar corona is expected to occur in extremely thin current sheets of order 1-100 km. Emission from these

current sheets should be visible in coronal EUV emission lines. However, this spatial scale is far below the resolution of existing imaging instruments. Conventional optics cannot be easily manufactured with sufficient surface figure accuracy to obtain the required < 0.1 arcsec resolution. A photon sieve, a diffractive imaging element similar to a Fresnel zone plate, can be manufactured to provide a few 0.001 arcsec resolution, with much more relaxed tolerances than conventional imaging technology. A simple design for a sounding rocket payload is presented that obtains 80 mas (0.080 arcsec) imaging with a 100 mm diameter photon sieve to image Fe XIV 334 and Fe XVI 335. These images will not only show the structure of the corona at a resolution never before obtained, they will also allow a study of the temperature structure in the dissipation region.

201.03 – **Evidence for Wave Damping at at Low Heights in a Polar Coronal Hole**

Michael Hahn[1], E. Landi[2], D. W. Savin[1]
[1]*Columbia University,* [2]*University of Michigan.*
9:00 AM - 6:30 PM

Polar coronal holes are regions of open magnetic field and are the source of the fast solar wind. We have measured the widths of spectral lines from a polar coronal hole using the Extreme Ultraviolet Imaging Spectrometer onboard the Hinode satellite. Non-thermal broadening in polar coronal holes is believed to be proportional to the amplitude of Alfven waves propagating along these open field lines. We find that line widths decrease at relatively low heights. Previous observations have attributed such decreases to systematic effects, but we find that

such effects are too small to explain our results. We conclude that the line narrowing is real, which suggests that Alfven waves are damped at unexpectedly low heights in a polar coronal hole. We derive an estimate for the upper limit for the energy dissipated between 1.1 and 1.3 solar radii and find that it is enough to account for up to 70% of that required to heat the polar coronal hole and accelerate the solar wind.

201.04 – **Plasma Blobs in the Solar Polar Regions: Outflows or Waves?**

Nour-Eddine Raouafi[1], P. N. Bernasconi[1], M. K. Georgoulis[2]

[1]*Johns Hopkins University/Applied Physics Laboratory,* [2]*RCAAM, Academy of Athens, Greece.*

9:00 AM - 6:30 PM

We analyze EUV images from the Solar Dynamic Observatory (SDO). Anti-sunward propagating blob are found almost everywhere within the solar polar regions with velocities ranging from a few 10 km s-1 to more than 100 km s-1. These structures are either flows or waves. In the former case they may reflect the structure of the nascent fast solar wind. The case is also important for the heating of the coronal plasma.

201.05 – **A Comparative Evaluation of Automated Solar Filament Detection**

Michael Schuh[1], J. Banda[1], P. Bernasconi[2], R. Angryk[1], P. Martens[1]

[1]*Montana State University,* [2]*Johns Hopkins University.*

9:00 AM - 6:30 PM

We present a comparative evaluation for automated filament detection in H-alpha solar images. By using metadata produced by the Advanced Automated Filament Detection and Characterization Code (AAFDCC) module, we adapted our Trainable Feature Recognition (TFR) component to accurately detect regions in solar images containing filaments. We first analyze the module's metadata and then transform it into labeled datasets for machine learning classification. Visualizations of data transformations and classification results are presented and accompanied by statistical findings. Our results confirm the reliable event reporting of the AAFDCC module as well as our ability to effectively detect solar filaments with our TFR component.

201.06 – **Magnetic Shear, Rayleigh-Taylor Instability, And Prominence Threads**

C. Richard DeVore[1]

[1]*NRL.*

9:00 AM - 6:30 PM

One striking feature of solar prominences is their very long, narrow threads of cool plasma that are observed in emission above the limb (and in absorption against the disk in filaments). It is generally accepted that this structure illuminates the prominence magnetic field, which both mechanical supports the cool mass against gravity and thermally insulates it against conduction from the surrounding hot corona. A mystery yet to be resolved is the origin of the narrow widths of prominence threads. We are investigating the hypothesis that it is fixed by a competition between the gravitational instability of a dense fluid (the prominence) residing above a dilute fluid (the corona) and the stabilizing influence of magnetic tension forces when the prominence field is distorted. It is well known (e.g., Stone & Gardiner 2007) that this process leads to the formation of ropes of dense fluid whose characteristic lengths are long parallel to the field (minimizing the increase in magnetic energy) but arbitrarily short perpendicular to the field (maximizing the release of gravitational energy). A key issue that has yet to be addressed is the effect on the Rayleigh-Taylor instability of shear in a magnetic field whose direction rotates continuously through the body of the prominence. Linear analysis indicates that marginal stability is reached for aspect ratios (parallel to perpendicular wavelengths) of about 25:1 for solar parameters; unstable modes have still larger ratios. High-resolution numerical simulations of initially monolithic slab prominences show developing fragmentation of the prominence/corona interface driven by the early, linear growth of the shear-modified Rayleigh-Taylor instability. Our investigation also is probing the nonlinear consequences of this evolution.

This work was supported by NASA's LWS TR&T program.

201.07 – **Multi-wavelength Observations Of The Evolution Of A Multi-filament Complex**

David Alexander[1], C. Zhu[1]

[1]*Rice Univ..*

9:00 AM - 6:30 PM

The strong and clear association between eruptive filaments and the production of solar flares and CMEs provides a natural starting point from which to explore the connections between solar conditions and eruptive events. The development of the filament in the build up to any eruption is critical to understanding how eruptions occur. We use high cadence ground-based observations from the Mauna Loa Solar Observatory (MLSO), in conjunction with complementary data from SDO, and STEREO to quantify the development of a multipolar magnetic complex comprising several distinct filaments, that formed in a decaying active region group over the course of November/December 2011. Two neighboring filaments in this complex erupt within 6 hours of each other on 2011 December, 25. In this paper we describe the evolution of this complex over the course of its development across the solar disk, as viewed from STEREO A, B and SDO, and discuss the role played by the field development, filament dynamics and twisting motions in forming the filament complex, initiating the eruptions, and controlling the subsequent reformation of the filament channels. The MLSO CHIP instrument, in particular, allows for some measure of Doppler velocity discrimination in the He I line at 10830Å providing a unique diagnostic capability for determining the strength and location of the filament dynamics, particularly the twisting and writhing motions in the erupting filaments. These data are combined with a 3D reconstruction using STEREO EUVI and SDO AIA data to better determine the 3D velocity evolution and spatial distribution of the twist.

201.08 – **Statistical Analysis of Eruptive Events Reported by the Flare Detective Module**

Henry D. Winter, III[1], P. Testa[1]

[1]*SAO.*

9:00 AM - 6:30 PM

As part of the Feature Finding Team (FFT) software suite the Flare Detective Module automatically detects and characterizes solar flares observed with the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO). Basic quantities such as time intervals, positions, and peak fluxes have been calculated and provided to the Heliophysics Event Knowledgebase (HEK) to allow the module to keep up with the extremely large size of the incoming data stream and provide near real-time information for space weather monitoring. Physically important parameters such as temperatures and emission measures, projected areas, light-curves, etc., are calculated in a second, post-processing step. While flares have been traditionally studied in isolation, the wealth of information provided by the Flare Detective Module allows for the study of the distribution flare properties across a large number of events. In this work we will investigate the correlation between the clustering of eruptive events with flare parameters such as peak temperature, duration, and projected extent of flares, as well as present other examples of statistical analyses that are possible with the Flare Detective Module.

201.09 – **Dynamic Evolution of Active Region Flux Tubes in the Turbulent Convective Envelope of a Young Sun: Solar-like Fast Rotators**

Maria A. Weber[1], B. P. Brown[2], Y. Fan[1]

[1]*High Altitude Observatory,* [2]*Department of Astronomy and Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, University of Wisconsin - Madison.*

9:00 AM - 6:30 PM

Our Sun rotated much more rapidly when it was younger, as is suggested by observations of rapidly rotating solar-like stars and the influence of the solar wind, which removes angular momentum from the Sun. By studying how flux emergence may have occurred on the young Sun, we are likely to learn more about the nature of the solar dynamo early in the Sun's history, as well as other solar-like stars. To investigate this, we embed a toroidal flux tube near the base of the convection zone of a rotating spherical shell of turbulent convection performed for solar-like stars that rotate 3, 5, and 10 times the current solar rate. Our objective is to understand how the convective flows of these fast rotators can influence the emergent properties of flux tubes which would rise to create active regions, or starspots, of a variety of magnetic flux strengths, magnetic fields, and initial latitudes. Flux tube properties we will discuss include rise times, latitude of emergence, and tilt angles of the emerging flux tube limbs with respect to the east-west direction. Also of interest is identifying the regimes where dynamics of the flux tube are convection dominated or magnetic buoyancy dominated, as well as attempting to identify active longitudes.

201.1 – **Particle-In-Cell Simulations of Particle Energization from Low Mach Number Fast Mode Shocks Using the Moving Wall Boundary Condition**

Jared C. Workman[1], J. Park[2], E. Blackman[2], C. Ren[2], R. Siller[2]

[1]*Colorado Mesa University,* [2]*University of Rochester.*

9:00 AM - 6:30 PM

Astrophysical shocks are often studied in the high Mach number limit but weakly compressive fast shocks can occur in magnetic reconnection outflows and are considered to be a site of particle energization in solar flares. Here we study the microphysics of such perpendicular, low Mach number collisionless shocks using two-dimensional particle-in-cell (PIC) simulations with a reduced ion/electron mass ratio and employ a moving wall boundary method for initial generation the shock. This moving wall method allows for more control of the shock speed, smaller simulation box sizes, and longer simulation times than the commonly used fixed wall, reflection method of shock formation. Our results, which are independent of the shock formation method, reveal the prevalence shock drift acceleration (SDA) of both electron and ions in a purely perpendicular shock with Alfven Mach number MA = 6.8 and ratio of thermal to magnetic pressure $\beta = 8$. We determine the respective minimum energies required for electrons and ions to incur SDA. We derive an theoretical electron distribution via SDA that compares favorably to the simulation results. We also show that a modified two-stream instability due to the incoming and reflecting ions in the shock transition region acts as the mechanism to generate collisionless plasma turbulence that sustains the shock.

201.11 – **The IBIS Mosaic - A Broad View Of The Solar Atmosphere**

Kevin P. Reardon[1], G. Cauzzi[1]

[1]*INAF - Oss. Astrofisico di Arcetri, Italy.*

9:00 AM - 6:30 PM

We present a unique set of observations spanning the photosphere and chromosphere with a large field-of-view (4 x 4 arcminutes) ,high-spatial resolution (0.1"/pixel), and full spectral profiles (R ~ 200,000). The data were obtained with the IBIS imaging spectrometer at the NSO/Dunn Solar Telescope on August 3, 2010 using a mosaic technique to tile an active region and surrounding areas. Spectral profiles were obtained in the chromospheric Hα, CaII 854.2 nm, and He I D3 lines, as well as photospheric FeI 543.4 nm. Combining this dataset with simultaneous SDO/AIA and SDO/HMI images and magnetic field measurements allow a highly comprehensive view of an entire volume of the solar atmosphere

from photosphere to corona. The wealth of information is used to explore the nature of the chromospheric fibrillar structures and their relationship with the overlying corona.

201.12 – **Particle Dynamics In The Reconnecting Heliospheric Current Sheet: Solar Wind Data Versus 3d PIC Simulations**

Valentina Zharkova[1], O. Khabarova[2]

[1]University of Bradford, United Kingdom, [2]IZMIRAN, Russian Federation.

9:00 AM - 6:30 PM

In this paper trajectories, densities, velocity and pitch angle distributions of particles accelerated by a super-Dreicer electric field are investigated with 2.5D full kinetic particle-in-cell (PIC) approach in the heliospheric current sheet (HCS) assumed to undergo a slow magnetic reconnection process with magnetic field configurations deduced from the solar wind observations.This approach reveals that during motion in a current sheet both kinds of particles, electrons and protons, are to be separated, either fully or partially, with respect to its midplane that can lead to their ejection to the opposite semiplanes that was also observed during the HCS crossings. This separation is found to form Hall's currents and polarisation electric field across the current sheet, which distribution over the current sheets allows to reproduce the magnitudes and temporal profiles of proton and ion velocities measured across the sector boundary (current sheet midplane).This separation process, in turn, divides both kinds of particles on 'transit' and 'bounced' ones depending on a side of the current sheet where they enter it and where they are supposed to be ejected. The transit and bounced protons reproduce rather closely the measured distributions of proton/ion densities about the current sheet midplane with a larger maximum occurring at the heliospheric sector boundary to be formed by the bounced protons and the other two smaller maximums on both sides from the central one to be formed by 'transit' protons. The observed electron distributions of density and energy before and after SBCs are found to fit the simulated ones revealing a sharp increase of density from one side from the HCS boundary and a depression from the other side.The bounced electrons are shown responsible for the increased density of electrons detected at some distance from the HCS boundary (midplane) with the shoe-like or medallion-type distributions in pitch angles.

201.13 – **Multiscale Dynamics of Interacting Solar Structures**

Vadim Uritsky[1], J. M. Davila[2]

[1]CUA at NASA/GSFC, [2]NASA/GSFC.

9:00 AM - 6:30 PM

Sun is an inherently complex and multiscale system which continues to challenge theorists and experimentalists alike. Coronal holes with scales typically on the order of a solar radius are the sources of high speed solar wind streams, and coronal active region magnetic loops, with typical scales of 10,000 km, exhibit somewhat steady heating. Direct heating of the coronal plasma, unresolved in current instruments, takes place at a typical ohmic dissipation scale in the corona, which is likely to be as small as 100 km. The Sun also exhibits a broad range of temporal scales. The largest features are observed to last for months. Coronal holes and coronal streamers can persist for several 27-day solar rotations with little change, while solar flares release a vast amount of energy essentially doubling the solar luminosity for a brief period of a few minutes. It is widely believed that the ultimate power source for all energy release processes in the upper solar atmosphere is convection at the solar surface mediated by magnetic field. Multiscale and nonlocal nature of this process often prevents its direct identification. Here, we present a new data analysis framework capable of identifying multiscale spatiotemporal causality between the photospheric magnetic field and coronal dissipation. The method involves spatiotemporal tracking of photospheric magnetic structures and coronal heating events, and their cross-correlation analysis based on a generalized correlation integral algorithm. The algorithms use no a priori assumptions regarding the intrinsic spatial and temporal interaction scales. The performance of the developed approach in identifying unstable magnetic configurations controlling coronal dissipation and heating is demonstrated on a variety of solar conditions, including quiet Sun and a solar active region in flaring and quiescent states.

201.14 – **Solar Bolometric Imager for Investigating the Sources of Solar Irradiance Variability**

Pietro N. Bernasconi[1], P. V. Foukal[2]

[1]JHU/APL, [2]Heliophysics Inc..

9:00 AM - 6:30 PM

The Solar Bolometric Imager is an innovative instrument for the investigation of the sources of solar irradiance variability. It makes precise, wavelength-integrated, photometric measurements of the irradiance variations originating in the solar photosphere. It provides images with spectrally flat response over the range 200-2600 nm, which includes about 95% of the total solar irradiance (TSI). It is important to realize that the SBI measures broad band contrast of thermal structures relative to their surroundings, so it does not require absolute accuracy or even high long term reproducibility. Its angular resolution (1 arcsecs/pixel) and field of view (320x240 arcsecs) are optimized to discriminate between TSI contributions from different magnetic and non-magnetic solar regions. The detector is an uncooled bolometric array with 320x240 ferro-electric pixels, coated with gold-black to achieve uniform sensitivity at all wavelengths of incident light. We are in the process of developing a space based SBI that builds upon the heritage of a stratospheric balloon-borne instrument successfully flown in 2003, and 2007. A space-based SBI will directly attack one of the most challenging problems in solar research: “What are the origins of long term solar total output variation on centennial and millennial time scales?” In addition, SBI measurements will continue to increase our understanding of solar magneto-convection, and more generally the underlying physics of solar magnetic variability.

Here we present the results of our latest instrument development efforts aimed at bringing the current SBI prototype to a Technology Readiness Level suitable for a SMEX or a Mission of Opportunity.

201.15 – **Differential Emission Measure Analysis for AIA and XRT Observations of Comet Lovejoy (C/2011 W3)**

Patrick McCauley[1], S. H. Saar[1], J. Raymond[1], L. E. Golub[1]

[1]Smithsonian Astrophysical Observatory.

9:00 AM - 6:30 PM

We present observations of Comet Lovejoy (C/2011 W3) recorded by the Atmospheric Imaging Assembly (AIA) aboard the Solar Dynamics Observatory (SDO) and the X-Ray Telescope (XRT) aboard the Hinode satellite. Lovejoy, a member of the Kreutz family of sungrazing comets, came to within 1.2 solar radii during its perihelion approach and escaped, despite expectations to the contrary, on December 6, 2011. The most significant sungrazer since the launch of SDO, Lovejoy provides an unprecedented opportunity to examine the effects of a comet traversing the solar corona. Both the ingress and egress were detected in seven AIA passbands (131, 171, 193, 211, 304, 335, and 1600 Angstroms), with XRT successfully imaging the outbound trip using its Al-mesh filter. We estimate the temperature structure of the emitting plasma using a differential emission measure analysis and explore interactions with the solar magnetic field. In several cases, secondary lines in a given channel appear to be the dominant comet-related emitters. Use of a radial filter for improved contrast of the faint cometary emission is also discussed.

201.16 – **WITHDRAWN: Multithermal Analysis of EIS Coronal Loops**

Brian T. Worley[1], J. T. Schmelz[1], S. Pathak[1]

[1]The University of Memphis.

9:00 AM - 6:30 PM

Four separate active regions containing multiple coronal loops were selected for Differential Emission Measure (DEM) analysis from Hinode Extreme ultraviolet Imaging Spectrometer (EIS) data. Each loop was chosen based on its location and our ability to find a clean nearby area for background subtraction. Our analysis uses iron lines with ionization stages from Fe VIII to Fe XVI in the wavelength ranges 170 - 210 and 250 - 290 A. The twelve selected loops were then analyzed to determine if their cross-field temperature was isothermal or multithermal. This was accomplished by averaging the intensities of ten individual pixels along the length of each loop and subtracting the average intensity of ten nearby background pixels. We then used these background-subtracted values, the density from a density-sensitive line ratio, and the atomic data from the CHIANTI database to create a DEM curve for each loop. Solar physics research at the University of Memphis is supported by NSF ATM-0402729 as well as a Hinode subcontract from NASA/SAO.

201.17 – **Automatic Detection and Characterization of EIT Waves Observed by AIA Data**

Jack Ireland[1], S. Christe[2], V. K. Hughitt[1], A. Y. Shih[2], C. A. Young[1], M. D. Earnshaw[3], F. Mayer[4]

[1]ADNET Systems, NASA's GSFC, [2]NASA's GSFC, [3]Blackett Laboratory, Imperial College, London, United Kingdom., United Kingdom, [4]Technische Universitat Wien, Vienna, Austria, Austria.

9:00 AM - 6:30 PM

EIT waves were first observed by SOHO-EIT in 1996. Many questions still remain about their relationship to other phenomena as such as CMEs, Moreton waves, and transverse coronal loop oscillations. This is partly due to the limitation of past observations, such as limited time cadence. With the new Atmospheric Imaging Assembly (AIA) onboard SDO, we now have access to an unprecedented uninterrupted data set with a full-Sun field of view, high dynamic range, and most importantly a high time cadence (~10 s). The higher cadence of AIA compared to other instruments means that it is possible to obtain more, and better information on the occurrence rates and properties of EIT waves. In order to fully utilize the vast

data archive of AIA, we are developing an automated algorithm to detect EIT waves. Such an algorithm will permit statistical analyses to be performed on these waves providing important constraints on models. We compare results using different image processing methods developed in Python, a general purpose scientific computing language widely used by multiple communities. We validate these algorithms against traditional human-powered methods. This analysis makes use of the SunPy python library.

201.18 – **Properties of Polar Coronal Jets in the Fast Solar Wind**

Mari Paz Miralles[1], S. R. Cranmer[1], J. C. Raymond[1], G. Stenborg[2]

[1]Harvard-Smithsonian CfA, [2]School of Physics, Astronomy and Computational Sciences, College of Science, George Mason University.

9:00 AM - 6:30 PM

We present results of an ongoing observational study of the main properties of polar coronal jets and how they interact with the surrounding corona. While magnetic reconnection is considered the prime driving mechanism of the ejected plasma, the processes at work during reconnection are not yet completely understood. We use multi-instrument measurements to probe the jet plasma, and we trace polar jets from their reconnection sites into the fast solar wind. This study will put firm constraints on the mechanisms driving the jets and on the relative contribution of jets to the overall fast solar wind.

This work is supported by NASA grant NNX09AH22G to the Smithsonian

Astrophysical Observatory.

201.19 – **Jet Statistics with the Automatic Jet Detections Module**

Antonia Savcheva[1]

[1]*Boston Univ..*

9:00 AM - 6:30 PM

We present the automatic jet detection module as part of the SDO Science Center. We give the methodology behind detecting jets in polar coronal holes and the automatic detection of jet parameters, such as velocities, lengths, lifetimes, widths. Examples of

individual events show how the algorithm for finding the jets and determining the parameters work.

Applying the program to the 1st year of AIA observation gives us statistical sample of hundreds of jets. Using this data we can estimate to mass load to solar wind.

201.2 – **Fast EUV Dimming Associated with a Coronal Jet Seen in Multi-Wavelength and Stereoscopic Observations**

Kyoung-Sun Lee[1], D. E. Innes[2], Y. Moon[1], K. Shibata[3], J. Lee[1]

[1]*Kyung Hee University, Korea, Republic of,* [2]*Max-Planck Institute for Solar System Research, Germany,* [3]*Kwasan and Hida observatory, Kyoto University, Japan.*

9:00 AM - 6:30 PM

We have investigated a coronal jet observed near the limb on 2010 June 27 by the Hinode/X-Ray Telescope (XRT), EUV Imaging Spectrograph (EIS), and Solar Optical Telescope (SOT), and the SDO/Atmospheric Imaging Assembly (AIA), Helioseismic and Magnetic Imager (HMI), and on the disk by STEREO-A/EUVI. From EUV (AIA and EIS) and soft X-ray (XRT) images we have identified both cool and hot jets. There was a small loop eruption in Ca II images of the SOT before the jet eruption. We found that the hot jet preceded its associated cool jet by about 2 minutes. The cool jet showed helical-like structures during the rising period. According to the spectroscopic analysis, the jet's emission changed from blue to red shift with time, implying helical motions in the jet. The STEREO observation, which enabled us to observe the jet projected against the disk, showed that there was a dim loop associated with the jet. We measured a propagation speed of ~ 800 km s^{-1} for the dimming front. This is comparable to the Alfven speed in the loop computed from a magnetic field extrapolation of the HMI photospheric field measured 5 days earlier and the loop densities obtained from EIS Fe XIV λ 264.79/274.20 line ratios. We interpret the dimming as indicating the presence of Alfvenic waves initiated by reconnection in the upper chromosphere.

201.21 – **Acoustic-Gravity Waves in the Solar Atmosphere: Comparing Hinode/SP Observations with Numerical Simulations**

Bernard Fleck[1], T. Straus[2], G. Severino[2]

[1]*ESA Science Operations Department,* [2]*INAF/OAC, Italy.*

9:00 AM - 6:30 PM

We investigate the signatures of acoustic-gravity waves in Hinode/SP observations and compare them to those found in line spectra synthesized from high-resolution 3D radiation-hydrodynamics simulations. The Hinode/SP time series extends over 4 hours, with a cadence of 16 s and a spatial resolution of 0.16 arcsec/pixel. The observations are compared to two numerical simulations of the Sun's surface layers, both computed with the radiation hydrodynamics code CO^5BOLD. The higher resolution simulation has a fixed 3D Cartesian grid with 400 x 400 x 300 cells, each of size 14 km x 14 km x 7.5 km, the lower resolution simulation 200 x 200 x 250 cells, each of size 56 km x 56 km x 21 km. The higher resolution simulation thus covers a cube of 5.6 x 5.6 x 2.3 Mm^3, the lower resolution simulation a cube of size 11.2 x 11.2 x 5.2 Mm^3. A line-synthesis code, based on the assumption of local thermodynamic equilibrium (LTE), was fed with the physical parameters of the simulations to produce synthetic, two-dimensional spectra of the photospheric lines of Fe 6301/6302 Å (Hinode/SP), Fe 6173 Å (SDO/ HMI), and Ni 6768 Å (SOHO/MDI). The resulting Doppler velocity time series are analyzed using Fourier techniques and compared to the observed Hinode/SP spectra. The height-dependent energy flux in the simulations is determined in the acoustic, evanescent and internal gravity wave regime and compared to energy flux estimates from the Hinode observations and the synthesized Doppler velocities of the simulations.

201.22 – **Supporting Solar Physics Research via Data Mining**

Rafal Angryk[1], J. Banda[1], M. Schuh[1], K. Ganesan Pillai[1], H. Tosun[1], P. Martens[1]

[1]*Montana State University.*

9:00 AM - 6:30 PM

In this talk we will briefly introduce three pillars of data mining (i.e. frequent patterns discovery, classification, and clustering), and discuss some possible applications of known data mining techniques which can directly benefit solar physics research. In particular, we plan to demonstrate applicability of frequent patterns discovery methods for the verification of hypotheses about co-occurrence (in space and time) of filaments and sigmoids. We will also show how classification/machine learning algorithms can be utilized to verify human-created software modules to discover individual types of solar phenomena. Finally, we will discuss applicability of clustering techniques to image data processing.

201.23 – **Content-based Image Retrieval For Solar Physics: First Steps And A Practical Demonstration.**

Juan Banda[1], R. Angryk[1], P. Martens[1]

[1]*Montana State University.*

9:00 AM - 6:30 PM

In this Demo/Presentation, we will introduce our open source framework for the creation of large-scale content-based image retrieval systems that is being for the NASA's SDO mission. In this step-by-step presentation we will show and talk about each of the components that comprised our framework and describe their individual use. Before finishing, we will also demonstrate our demo version of the CBIR system that is in development for NASA's SDO mission. Since this is an open tool for researchers, we will be gathering suggestions and comments from the participants in order to provide a more functional package for the solar physics community.

201.24 – **The Virtual Solar Observatory: What Are We Up To Now?**

Joseph B. Gurman[1], F. Hill[2], F. Suàrez-Solà[2], R. Bogart[3], A. Amezcua[3], P. Martens[4], J. Hourclé[1], K. Hughitt[1]

[1]*NASA GSFC,* [2]*NSO,* [3]*Stanford University,* [4]*Montana State University.*

9:00 AM - 6:30 PM

In the nearly ten years of a functional Virtual Solar Observatory (VSO), http://virtualsolar.org/, we have made it possible to query and access sixty-seven distinct solar data products and several event lists from nine spacecraft and fifteen observatories or observing networks. We have used existing VSO technology, and developed new software, for a distributed network of sites caching and serving SDO HMI and/or AIA data. We have also developed an application programming interface (API) that has enabled VSO search and data access capabilities in IDL, Python, and Java.

We also have quite a bit of work yet to do, including completion of the implementation of access to SDO EVE data, and access to some nineteen other data sets from space- and ground-based observatories. In addition, we have been developing a new graphic user interface that will enable the saving of user interface and search preferences. We solicit advice from the community input prioritizing our task list, and adding to it.

201.25 – **Solar Tiling And Tracking Extraction Service Using The VSO API As The Backend**

Alisdair R. Davey[1], I. Suarez Sola[2], E. Gonzalez Suarez[3], I. Gonzalez Hernandez[2], F. Hill[2], J. Hourcle[4], VSO Team

[1]*SAO,* [2]*NSO,* [3]*Imperial College London, United Kingdom,* [4]*SDAC.*

9:00 AM - 6:30 PM

In solar research it is often necessary to isolate areas of the Sun for further studies. Most scientists develop their own set of tools to extract the areas in which they are interested and build temporal series that include selected solar phenomena, however the overwhelming amount of available solar data, especially since the launch of SDO (Solar Dynamics Observatory), makes it difficult for researchers to access selected sets of data without downloading very large images.

With the help of one of the modules of the GONG (Global Oscillation Network Group) "ring-diagram'"pipeline and the VSO (Virtual Solar Observatory) API (Application Programming Interface), we build an asynchronous Solar data cube extraction service for GONG, SOLIS (Synoptic Optical Long-term Investigations of the Sun) and SDO data. The service has a simple ad-hoc HTML front end for researchers to access it.

The data cube extraction service takes as input as set of solar coordinates, a period of time, the size of the requested area, the spatial resolution needed, projection to use (cylindrical or postel) and the images to work on. The service then tracks the sun and corrects for standard solar rotation effects. The extracted files are saved to a staging area and the user is notified via email or a SOAP callback function that the processed images are available for download.

201.26 – **Photometric Uncertainties within Hinode XRT**

Adam Kobelski[1], S. H. Saar[2], M. A. Weber[2], D. E. McKenzie[1], K. K. Reeves[2]

[1]*Montana State University,* [2]*Harvard-Smithsonian Center for Astrophysics.*

9:00 AM - 6:30 PM

We have developed estimates of the systematic uncertainties for the X-Ray Telescope (XRT) on Hinode. These estimates are included as optional returns from the standard XRT data reduction software, xrt_prep.pro. Included in these software estimates are uncertainties from instrument vignetting, dark current subtraction, split bias leveling, Fourier filtering and JPEG compression. Sources of uncertainty that rely heavily on models of plasma radiation or assumptions of elemental abundances, such as photon noise, are discussed, but not included in the software. It will be shown that the photon noise is much larger than the systematic uncertainty.

This work is supported by NASA under contract NNM07AB07C with the Harvard-Smithsonian Astrophysical Observatory

201.27 – **Recommendations for Data & Software Citation in Solar Physics**

Joseph Hourcle[1]

[1]*NASA/GSFC (Wyle).*

9:00 AM - 6:30 PM

We present a series of recommendations to improve the citation of solar physics data to ensure validation and reproducibility.

We include recommendations for data providers to make their data more easily cited by in solar physics and the wider scientific community, as well as recommendations for authors who are using the data.

We hope to improve the acknowledgement rate of not only solar physics data but also the tools used by our community, so that we can ensure continued maintenance and availability of the infrastructure used by the science community.

We also hope to establish guidelines for describing the history of the data that may be necessary for verification of the research, including the original source, and the methods and tools used in processing the data for analysis.

201.28 – **Best Practices for FITS Headers**

Joseph Hourcle[1]
[1]*NASA/GSFC (Wyle).*
9:00 AM - 6:30 PM

We present recommendations and an example of best practices for FITS headers to improve documentation and usability of solar physics data distributed as FITS files.

We built on existing norms and standards, including 'Proposed Keywords for SOHO' and the FITS World Coordinate System (WCS) conventions, and include recommendations on the use of FITS features and extensions to help make data stored and distributed in FITS better suited for both present-day usage and long-term archiving.

Our goals include:

1. Allow both solar physicists and non-discipline scientists to easily understand what's in a file from an instrument they've never dealt with before.

2. Allow scientists to quickly determine if the file contains data that is useful for their purposes.

3. Allow scientists to find where to get additional information on how to properly use the data.

4. Reduce the likelihood of keywords or data being misunderstood.

5. Ensure the data is accessible, understandable and usable over the long-term.

6. Reduce barriers to acknowledgement and citation of data.

7. Provide for reliable identification of files and observations that maybe be stored in multiple locations or forms.

8. Provide a framework to denote mission- or instrument-specific keywords.

9. Give data providers a template to work from when designing FITS headers for new missions.

201.29 – **Calibration of Hinode/XRT for Coalignment**

Keiji Yoshimura[1], D. E. McKenzie[1]
[1]*Montana State University.*
9:00 AM - 6:30 PM

When someone tries to understand some phenomena on the Sun, a comparison between the data from different types of observation for the same target would be a good way. Fortunately various kinds of data, from satellite and ground-based telescopes, are available for us these days. While it is necessary to coalign the data from different instruments for the analysis, it is often difficult to achieve sufficient accuracy with a simple method. For the coalignment, we need to know the plate scales, rotation angle in the plane of the sky, and pointing information for the images, at least. To augment the information provided by the Hinode/XRT FITS headers, we are calibrating the XRT data as accurately as possible by means of limb fitting and cross correlation techniques, yielding a table of coalignment parameters for every single XRT image. The final goal of the project is to provide an easy and precise

coalignment method to users of the XRT data. We also do a cross calibration between XRT and AIA on-board SDO. Since we can find many similar structures in some of the images from both of the instruments, a cross correlation technique is useful for improving the accuracy of the coalignment. Our parameter tables will include the results from the cross calibration too.

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201 – Solar & Stellar

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

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201 – Solar & Stellar

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

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201 – Solar & Stellar

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

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202 – Coronal Magnetic Fields

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

202.01 – **The Solar Polar Coronal Holes in Solar Cycle 24**

Shea Hess Webber[1], N. Karna[1], W. D. Pesnell[2], M. S. Kirk[3]
[1]*GMU,* [2]*NASA GSFC,* [3]*NMSU.*
9:00 AM - 6:30 PM

We have measured the area of the solar polar coronal holes in both hemispheres. One data series uses synoptic maps from two instruments on SOHO and the AIA instrument on SDO. The other used the perimeter tracking method on data from SoHO EIT. This allows us to calculate the areas of the solar polar coronal holes from the beginning of Solar Cycle 23 up to late 2010. This method used synoptic maps constructed from 170 Carrington Rotations of the 171, 195, and 304 Å channels of the Extreme-ultraviolet Imaging Telescope (EIT) on SoHO. Our second method used synoptic maps constructed from the Michelson Doppler Imager (MDI) for 187 Carrington Rotations from mid 1996 through 2010. In this method, polar coronal holes are easily distinguished from the equatorial coronal hole regions. The north and south polar hole areas were noticeably smaller in the recent minimum than they were at the beginning of Solar Cycle 23. We compared these polar hole areas with the polar coronal hole area found using a perimeter tracking to analyze a series of 171, 195, and 304 Å full disk images from EIT to measure the perimeter of polar coronal holes as they appear on the limbs. It is found that both the Northern and Southern polar coronal hole areas obtained from the perimeter tracking method similar to those from the synoptic maps. The coronal hole areas will be compared with the polar magnetic fields to estimate what phase of the solar cycle the hemispheres have reached.

202.02 – **Coronal Holes, Filament Channels And Filaments: Observations Of The Self-organization Of The Coronal Magnetic Field Over Solar Cycles 23 And 24**

Olga Panasenco[1], S. F. Martin[1], M. Velli[2], M. A. Berger[3]
[1]*Helio Research,* [2]*Jet Propulsion Laboratory, California Institute of Technology,* [3]*University of Exeter, United Kingdom.*
9:00 AM - 6:30 PM

The aim of this work is to understand the relationship between coronal holes, coronal hole boundaries and one of the other main features of the coronal magnetic field, namely filament channels, regions of highly sheared magnetic fields overlying photospheric polarity reversal boundaries. The well-developed filament channel is a necessary ingredient for filament formation. Polar coronal holes and polar crown filament channels always seem to exist together, and even during periods of weakest activity, when nothing indicates the presence of polar crown channels on the solar disk, polar crown prominences appear at the limb proving their existence. Does a similar symbiotic relationship exist also for other coronal holes? There is some indication that for middle and low latitude coronal holes different configurations occur depending on the polarity of the hole relative to the pole. If the polarity is the same, then a coronal pseudostreamer configuration can form with twin filament channels at its base, while if the polarity is opposite, the right conditions for the development of the filament channels and filaments following the hemispheric helicity rule arise. Using SOHO/EIT and MDI, STEREO/EUVI, SDO/AIA and HMI instruments we trace the formation and mutual evolution of coronal holes and their symbiotic filament channels up to and including filament formations, eruptions and subsequent reformations during period 1998-2012 (solar cycles 23 and 24).

202.03 – **The Effects Of B/L-dependent Heating On The Formation And Evolution Of A Multi-threaded Prominence**

Judith T. Karpen[1], M. Luna[2], C. DeVore[3]
[1]*NASA GSFC,* [2]*UMD/CRESST/NASA GSFC,* [3]*NRL.*
9:00 AM - 6:30 PM

We have developed a comprehensive, multi-threaded, three-dimensional model of the plasma dynamics and energetics of a prominence and its overlying arcade (Luna et al. 2012). In this model, the basic magnetic structure is that of two interacting sheared arcades, while the cool condensations comprising the prominence are formed by the well-studied thermal nonequilibrium mechanism. In a given filament-channel flux tube, the mass is evaporated from the chromosphere by heating localized near the footpoints, and condenses in the form of transient blobs or a persistent thread. Our previous studies of thermal nonequilibrium used steady or impulsive heating functions with no dependence on local physical variables. However, parametric active-region models with steady heating proportional to B/L, where B is the flux-tube magnetic field strength at the heated footpoint and L is the flux-tube length, yield the best agreement with observations (e.g., Schrijver et al. 2004). We have determined the effects of this active-region heating function on our model for the formation and evolution of prominence mass. We have also expanded the range of our computational domain to include more of the overlying arcade (the so-called “cavity”), and have increased the number of selected flux tubes from 125 to 533. We will illustrate the time-dependent plasma behavior produced by the B/L heating function with synthetic images in several AIA passbands, and compare the resulting prominence properties with those predicted by our model with flux-tube-independent heating.

202.04 – **Coronal Cavities from SDO Observations**

Nishu Karna[1], S. A. Hess Webber[1], W. D. Pesnell[2], J. Zhang[1], M. S. Kirk[3]
[1]*George Mason University,* [2]*Goddard Space Flight Center/ NASA,* [3]*New Mexico*

State University.
9:00 AM - 6:30 PM

Coronal cavities are circular darkened regions observed above the solar limb in white light and EUV coronal images. It is a region of low density relative to the surrounding corona. In this study, we are using synoptic maps made from EUV images from the Atmospheric Imager Assembly (AIA) instrument on the SDO to determine the structure and evolution of cavities. The synoptic maps, constructed from circular rings above the limb, are found to best show cavities in 211Å (Fe XIV, ~2.0 MK) and 193 Å (Fe XII, ~1.6 MK) pass bands. The high spatial and time resolution combined with the broad temperature coverage provides a consistent picture of the cavity material and the dynamics of the structure. Our goal is to study the cavity's sizes (height, diameter and length), density and temperature properties. Moreover, we will examine the correlation between cavity morphology and underlying magnetic field distribution using Heliosesmic and Magnetic imager (HMI) instrument on SDO. This study will shed light on the origin, evolution and dynamics of coronal cavities.

202.05 – **Morphology Of A Hot Prominence Cavity Observed With Hinode/XRT And SDO/AIA**

Mark A. Weber[1], K. K. Reeves[1], S. E. Gibson[2], T. A. Kucera[3]
[1]*SAO,* [2]*HAO/NCAR,* [3]*NASA/GSFC.*
9:00 AM - 6:30 PM

Prominence cavities appear as circularly shaped voids in coronal emission over polarity inversion lines where a prominence channel is straddling the solar limb. The presence of chromospheric material suspended at coronal altitudes is a common but not necessary feature within these cavities. These voids are observed to change shape as a prominence feature rotates around the limb. We use a morphological model projected in cross-sections to fit the cavity emission in Hinode/XRT passbands, and then apply temperature diagnostics to XRT and SDO/AIA data to investigate the thermal structure. We find significant evidence that the prominence cavity is hotter than the corona immediately outside the cavity boundary. This investigation follows upon ``Thermal Properties of A Solar Coronal Cavity Observed with the X-ray Telescope on Hinode'' by Reeves et al., 2012, ApJ, in press. M. Weber and K.K. Reeves are supported under contract NNM07AB07C from NASA to SAO. T. Kucera is supported by an award from the NASA SHP Program.

202.06 – **A New Perspective of Coronal-Loop EUV Emissions**

Yung Mok[1], R. Lionello[2], Z. Mikic[2], J. Linker[2]
[1]*Univ. of California, Irvine,* [2]*Predictive Science, Inc..*
9:00 AM - 6:30 PM

The formation mechanism of coronal loops and why they appear to have uniform cross section have been controversial. In general, the flux tubes of the active-region magnetic field expand in the corona, especially at locations where the field is nearly potential. Because the actual magnetic field, modeled in 3D based on a magnetogram, is complicated, the attempt to extract the underlying loop physics might have been hindered by the complexity of the field. We go back to basic by using a simple quadrupole field structure and applying a heating model in which heat is deposited mostly near the footpoint. Our 3D simulation demonstrates that this simple structure is able to reproduce loop-like structures in EUV. Although the flux tubes expand in the corona as expected, the EUV loops have remarkably uniform cross sections. The dynamic properties of these synthetic loops are to be compared with the observations.

Work supported by Heliospheric Theory Program of NASA

202.07 – **Topological Tools For The Analysis Of Active Region Filament Stability**

Edward E. DeLuca[1], A. Savcheva[1], A. van Ballegooijen[1], E. Pariat[2], G. Aulanier[2], Y. Su[1]
[1]*Harvard-Smithsonian, CfA,* [2]*Observatoire de Paris, France.*
9:00 AM - 6:30 PM

The combination of accurate NLFFF models and high resolution MHD simulations allows us to study the changes in stability of an active region filament before a CME. Our analysis strongly supports the following sequence of events leading up to the CME: first there is a build up of magnetic flux in the filament through flux cancellation beneath a developing flux rope; as the flux rope develops a hyperbolic flux tube (HFT) forms beneath the flux rope; reconnection across the HFT raises the flux rope while adding addition flux to it; the eruption is triggered when the flux rope becomes torus-unstable. The work applies topological analysis tools that have been developed over the past decade and points the way for future work on the critical problem of CME initiation in solar active regions. We will present the uses of this approach, current limitations and future prospects.

202.08 – **Temperature Analysis of an Active Region Core Loop Using AIA and XRT Data**

Jennifer W. Garst[1], J. Schmelz[1], J. Kimble[1]
[1]*Univ. Of Memphis.*
9:00 AM - 6:30 PM

Data obtained on December 10, 2010 by both the Atmospheric Imaging Assembly (AIA) and the X-Ray Telescope (XRT) are co-aligned and appropriately scaled in order to do a differential emission measure analysis of the combined data. This project uses Hybrid abundances from Fludra & Schmelz and atomic data from the CHIANTI atomic physics database to analyze an active region core loop and report on the multithermal analysis of the combined data set. The loop being analyzed is visible in the 94, 131, 171, 193, 211, 335 Å passbands on AIA; and the Al-thick, Ti-poly, Al-mesh, Al-poly/Ti-poly, C-Poly/Ti-poly, C-poly, Be-thin, Be-med, Al-med, and Al-poly filters on XRT. Solar physics research at the University of Memphis is supported by NSF ATM-0402729 as well as a Hinode subcontract from NASA/SAO.

202.09 – **Interdependence of Solar Plasma Flows and Magnetic Fields**

E. J. Zita[1], C. Smith[1], N. Hurlburt[2]
[1]*Evergreen St. College,* [2]*Lockheed Martin Solar Astrophysics Lab.*
9:00 AM - 6:30 PM

Interactions between flows and magnetic fields in the Sun's plasma can affect surface phenomena such as sunspots, can reveal deeper magnetic connections via changes in solar flows and oscillations, and drive dynamics in the long-term solar magnetic cycle, e.g. the recent "weird solar minimum."

We have observed changes in solar surface flow patterns consistent with the Proctor effect, which depends on magnetic field strength / orientation in active regions. Other investigators have observed relationships between solar torsional oscillations and mean field strengths. Zonal flow velocities correlate roughly with field strengths, and may serve as diagnostics or predictors of solar cycles. We explore a possible relationship between the Proctor effect and the magnetic interdependence of zonal flows. Our study potentially deepens understanding of fundamental solar magnetic dynamics underlying convection and dynamo processes.

This work was supported by NSF grant 0807651, NASA grants NAS5-38099, NNM07AA01C, NNG04EA00C, and Lockheed Martin Internal Research Funds.

202.1 – **Finding Electric Fields, Poynting and Helicity Fluxes from Vector Magnetograms**

Maria Kazachenko[1], G. H. Fisher[1], B. T. Welsch[1]
[1]*Space Science Laboratory, UC Berkeley.*
9:00 AM - 6:30 PM

Existence of systematic measurements of vector magnetic fields allows us to estimate electric field in the photosphere, using Poloidal-Toroidal Decomposition of the magnetic field and its partial time derivative (Fisher et l. 2011). The PTD method is based on solving a set of Poisson equations which in the past has been done using Fast Fourier Transform techniques. We modify the existing PTD method by improving the poisson solver using a package of solvers for elliptic partial differential equations called Fishpack. We apply the PTD with a new Poisson equation solver to several test cases with a known electric field. We find that for the ANMHD simulation test case application of the new poisson solver yields a more accurate values of electric field, Poisson and helicity fluxes than before. We further investigate the applicability of our method to other test cases using simulations of M. Cheung and Y. Fan and also HMI vector magnetograms.

202.11 – **The Coronal Solar Magnetism Observatory (COSMO)**

Steven Tomczyk[1]
[1]*HAO/NCAR.*
9:00 AM - 6:30 PM

Measurements of coronal and chromospheric magnetic fields are arguably the most important observables required in our understanding of the emergence of magnetic flux into the solar atmosphere and the processes responsible for the production of solar activity, coronal heating and coronal dynamics. However, routine observations of the strength and orientation of coronal and chromospheric magnetic fields are not currently available. The Coronal Solar Magnetism Observatory (COSMO) is a proposed ground-based suite of instruments designed for routine study of coronal and chromospheric magnetic fields and their environment. We will present an overview of the COSMO and show recent progress in development of the COSMO observatory.

202.12 – **Pseudostreamers and Twin Filaments in the Solar Corona**

Olga Panasenco[1], M. Velli[2]
[1]*Helio Research,* [2]*Jet Propulsion Laboratory, California Institute of Technology.*
9:00 AM - 6:30 PM

Pseudostreamer configurations appear in globally unipolar regions above multiple polarity reversal boundaries, and are a generic feature which seems to be important for coronal physics. On small scales pseudostreamer configurations can support jets, or polar plumes. On large scales, some of these polarity reversal boundaries can be filament channels, and when this is the case they always occur as twin filament channels often containing twin filaments of the same chirality. The magnetic structure of pseudostreamers for cases with and without twin filaments lying at their base, as reconstructed with a PFSS model, is significantly different. Branches of pseudostreamers on opposite sides of the separatrix surface diverge when filaments are present, in association with the strong horizontal component of the field present in filament channels. Here we analyze possible magnetic field configurations of the complete pseudostreamer system and study the links between its separate parts, which include open field lines of pseudostreamers, filament channels, filaments, cavities, overlying filament arcades. Following the dynamical changes in the coronal pseudostreamer, we analyze the twin filament eruption due to new flux emergence and how the topology of the pseudostreamer gradually changes during the pre-eruptive and erupting phases. The presence of well developed filaments of the same chirality at the base of pseudostreamers implies sheared fields, which in the PFSS model are current-free, but are more generally consistent with the presence of a vertical pseudostreamer field-aligned current sheet. We discuss the 3D magnetic topology of the filament, filament cavity and overlying filament arcades for these twin systems and its implications on the theories for filaments, filament eruptions and CMEs.

202.13 – **Principle Component Analysis of the Solar Background and**

Sunspot Excess Magnetic Fields in the Cycles 21-23

Sergei Zharkov[1], V. Zharkova[2], S. Shepherd[2]

[1]*Mullard Space Science Laboratory/UCL, United Kingdom,* [2]*University of Bradford, United Kingdom.*

9:00 AM - 6:30 PM

In this study we carry out Principle Component Analysis (PCA) (a) the solar background magnetic field (SBMF) measured by the Wilcox Solar Observatory with low spatial resolution for solar cycles 21-23, and, (b) the sunspot excess magnetic field (SEMF) in cycle 23 obtained by SOHO/MDI. PCA analysis reveals two independent temporal SBMF components of opposed polarities originating in the opposite hemispheres and running noticeably off-phase (with about a two and half year delay), with their maxima overlapping in the most active hemisphere for a given cycle. Their maximum magnitudes are progressively reduced from cycle 21 to 23 while overlapping in the Northern hemisphere for cycles 21 and 22 and in the Southern one in cycle 22. The reduction of magnitudes and slopes of the maxima of the SBMF waves from cycle 21 towards cycle 23 leads us to expect lower magnitudes of the SBMF wave in cycle 24. These SBMF waves modulate the occurrence and magnitudes of sunspot excess magnetic field in time and latitude. Also PCA allowed us to detect 4 pairs of independent SBMF components in latitude. The latitudinal coupling of SBMF is comprised of eight independent principal components; the two main latitudinal components attributed to symmetric and another six assigned to asymmetric types of meridional flows.

Similar components were found in the SEMF temporal and latitudinal distributions for cycle 23 revealing the polarities opposite to the SBMF polarities with the double maxima corresponding to the maxima of the SBMF residuals. The results allow us to postulate the existence of dipole and quadruple magnetic structures in the SBMF, which varies from cycle to cycle and takes the form of two waves travelling off phase, with a shift of one quarter of the cycle's period.

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202 – Coronal Magnetic Fields

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

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202 – Coronal Magnetic Fields

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

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202 – Coronal Magnetic Fields

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

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203 – Chromosphere & Transition Region

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

203.01 – **Helium D3 at High Resolution**

Kevin P. Reardon[1]

[1]*National Solar Observatory.*

9:00 AM - 6:30 PM

We present high-resolution observations of the Helium D3 (587.6 nm) line obtained with the IBIS imaging spectrometer at the Dunn Solar Telescope. The D3 line is observed both on-disk and off-limb in a variety of solar features. These observations reveal that structures in this line are both finely structured (at our resolution limit of ~0.2 arcsec) and highly dynamic. We use the observed spectral profiles to derive information on the local atmospheric properties. We compare the appearance of the D3 line with features seen in simultaneous Hα and Ca II 854.2 nm chromospheric observations, as well as SDO/AIA images of the transition region and corona. The fibrils observed in the He D3 line provide useful information on connectivity from the chromospheric layers up into the corona.

203.02 – **Multi-wavelength Spectropolarimetry Of A Sunspot Superpenumbra With Firs And Ibis**

Thomas A. Schad[1], A. Tritschler[2], M. J. Penn[2]

[1]*University of Arizona/National Solar Observatory,* [2]*National Solar Observatory.*

9:00 AM - 6:30 PM

Extending nearly radially from magnetic field concentrations like sunspot umbrae or pores, threadlike fibrils observed in the chromosphere and transition region host a variety of dynamic behavior and have long been considered local tracers for the magnetic field. Morphologically, fibrils are similar to spicules seen on the limb. The connectivity of fibrils outside of the magnetic field concentrations with the photosphere and/or corona is not well understood, and probing the magnetic field in these features remains challenging. In this contribution we describe multi-wavelength spectropolarimetric observations from the Dunn Solar Telescope in New Mexico using the Facility Infrared Spectropolarimeter (FIRS) and the Interferometric BiDimensional Spectropolarimeter (IBIS). FIRS performs high resolution slit spectropolarimetry in the He I triplet at 1083 nm, which is a promising diagnostic of chromospheric vector fields. Significant progress has been made to boost the accuracy and sensitivity of these measurements. Here we present measurements of an active region sunspot at a spatial resolution of 0.3 arcsec and an RMS noise in Stokes Q,U,V spectra down to 0.0003 in units of the local continuum (SNR > 3300). We perform full inversions of these spectra taking into account both Zeeman and Hanle effects. Initial results lend support for field-aligned fibrils near the penumbral boundary of a sunspot. Jointly with the FIRS observations, we use IBIS to observe the Stokes vectors of Ca II 854.2 nm and Fe I 617.3 nm and the intensity spectrum of H-alpha 656.3 nm. As a spectral imaging instrument, IBIS rapidly scans through the three spectral lines over a 45'' by 95'' FOV at an overall cadence of 50 seconds, allowing a much better description the dynamics of fibrils observed by both FIRS and IBIS.

203.03 – **PSF Equalization For MOSES**

Shane Atwood[1], C. Kanbelborg[1]

[1]*Montana State University.*

9:00 AM - 6:30 PM

Analysis of MOSES data requires quantitative comparison of three distinct images taken at different spectral orders. Each image has a different and unknown point spread function (PSF), which leads to artifacts in the recovered spectra. We demonstrate that it is possible to equilize the PSFs in all three images.

203.04 – **Oscillations of Rapid Blueshifted Events as Derived from NST Data**

Vasyl B. Yurchyshyn[1], A. Kilcik[1], V. Abramenko[1]

[1]*Big Bear Solar Obs..*

9:00 AM - 6:30 PM

We studied oscillations of type II spicules observed near the north pole of the sun. The study is based on high-resolution data recorded by the New Solar Telescope at the Big Bear Solar Observatory. The spicule oscillations were probed by applying the global wavelet method to a 34 min continuous time series of off-band Halpha images. The main findings are: i) Type II spicules are oscillating with about 1 min period, while the outside quiet regions show dominance of 3 min periods. ii) Spicules belonging to a cluster, tend to oscillate as a group. We will present details of these findings and discuss possible implications.

203.05 – **Spectropolarimetry in the Sodium 589.6nm D1 line: Evaluating the Resulting Chromospheric (?) Vector Field Maps.**

K D. Leka[1]

[1]*NorthWest Research Associates, INC..*

9:00 AM - 6:30 PM

Pioneering work by T. R. Metcalf almost two decades ago pointed to the Na 589.6nm D1 line as a contender for providing chromospheric vector magnetic field measurements (using the Zeeman effect). We report here on a systematic examination of what can be expected from Sodium 589.6nm spectropolarimetry, with respects to polarization-signal amplitudes and retrieval, and the implementation of the inversion for this line based on the Jeffries, Lites & Skumanich Weak-Field Approximation algorithm. The analysis is performed using both synthetic data and observations from the Imaging Vector Magnetograph, for which a large dataset of Sodium 589.6nm vector spectropolarimetry exists. The synthetic data are based on a 3-D field extrapolated from photospheric vector magnetograms of two active regions, four distinct model atmospheres coupled with NLTE synthesis of the emergent NaI D1 Stokes polarization spectra, computed for a variety of viewing angles. In this manner, a broad representation of active-region features, field strengths and observing angles are tested using ``hare & hound'' approaches, including evaluating algorithm performance in the presence of noise and instrumental effects. We compare retrieval algorithms for the very weak (as expected) polarization signals, and evaluate the retrieved vector magnetic field at a range of inferred heights. Finally, we provide an example from the IVM and discuss the prospects for obtaining and interpreting chromospheric vector magnetic field maps. Support for this work comes from NASA NAG5-12466, NASA NNH09CE60C, AFOSR F49620-03-C-0019, NSF/NSWP ATM-0519107, NSF/SHINE ATM-0454610, and NSF CRG ATM-0551055.

203.06 – **How Low−Quality Observations Affect Spicule Properties**

Tiago M. D. Pereira[1], B. De Pontieu[2], M. Carlsson[3]

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9:00 AM - 6:30 PM

Spicules have been observed on the sun for more than 80 years, in several chromospheric lines such as H-alpha and Ca II H. Recent work has shown that spicules have the potential to drive the solar wind and heat the chromosphere, making them a hotly contested topic in solar physics. Despite the wealth of observations available, their properties are still a matter of debate. Difficulties in measuring their properties arise because spicules occur on short spatial and temporal scales, and are very abundant (superimposed) at the limb. Most of the

older observations lacked either the spatial resolution or cadence necessary to measure spicules. This changed with Hinode/SOT, which has provided seeing-free observations with high cadence and spatial resolution. Using SOT observations, we find that in the quiet sun most spicules are shorter lived and can move much faster than previously measured. In this work we try to reconcile the recent results with results from older observations. We degrade SOT data to match the cadence and resolution of older data sets, and apply the same semi-automated method to detect and measure the properties of spicules to both the original and degraded data. We find that degrading the data has a significant effect on the measured properties of spicules. Most importantly, the results from the degraded data agree very well with older studies (e.g. mean spicule duration more than 5 minutes, and upward velocities of about 25 km/s). These results illustrate how the combination of spicule superposition, low spatial resolution, and cadence affect the measured properties of spicules, and that previous measurements can thus be unreliable.

203.07 – **UV Signatures of Flare Heating and Cooling**

Jiong Qiu[1], D. W. Longcope[1]

[1]*Montana State Univ..*

9:00 AM - 6:30 PM

A solar flare is comprised of impulsive energy release events by magnetic reconnection, which forms and heats flux tubes, the

elementary structure of flare loops. Recent studies have revealed a two-phase evolution pattern of UV 1600AA emission at the feet of these flux tubes: a rapid pulse lasting for a few minutes, followed by a gradual decay on timescales of a few tens of

minutes. These signatures are indicative of instantaneous lower-atmosphere response to impulsive energy deposition, and the subsequent plasma evolution in overlying coronal loops. We present analysis of the UV 1600AA emission at the foot-points of numerous reconnection-formed flux tubes observed by SDO/AIA, and discuss diagnostics of the lower-atmosphere and corona dynamics, which are governed by different but coherent physics during the heating and decay phases.

203.08 – **Radiative Transfer and Absorbing Structures in the Transition Region**

Jacob Plovanic[1], C. C. Kankelborg[1]

[1]*Montana State University.*

9:00 AM - 6:30 PM

A fully satisfactory explanation for the anomalous He II 304 Å intensity in the solar transition region has yet to be offered. As an extension of previous work, we use a full radiative transfer code to build a more consistent model of the transition region that allows the He II line to form with low filling factor and low opacity. Our results are constrained by the quiet sun center-to-limb profile of He II 304 Å obtained from the MOSES sounding rocket mission and by AIA full-disk data.

203.09 – **Ca II K And H Spectral Line Profiles From “Basal” And “Magnetic” Chromospheres**

Alexei A. Pevtsov[1], L. Bertello[1]

[1]*National Solar Observatory.*

9:00 AM - 6:30 PM

We use observations from the SOLIS’ Integrated Sunlight Spectrometer (ISS) to investigate properties of the Ca II K and H disk-integrated spectral line profiles. The ISS daily observations cover the period of declining phase of cycle 23 and rising phase of cycle 24. The contributions of “basal” and “magnetic” chromospheres were extracted from the observed profiles in order to investigate their solar-cycle dependency. Our analysis suggests that the properties of the "basal" chromosphere may change slightly with the cycle of activity.

203.1 – **Coordinated Observations Of On-disk Type II Spicules With IBIS And Hinode**

Xin Chen[1], D. Na[1], J. Jing[1], A. Tritschler[2], K. Reardon[3], H. Wang[1]

[1]*New Jersey Institute of Technology,* [2]*National Solar Observatory,* [3]*INAF - Osservatorio Astrofisico di Arcetri, Italy.*

9:00 AM - 6:30 PM

Ubiquitous small-scale spicules/jets in the chromosphere are believed to be an important ingredient contributing to coronal heating and solar wind by supplying energy and mass upwards. In particular, type II spicules discovered at the solar limb (De Pontieu et al. 2007) and their highly probable chromospheric on disk counterpart "Rapid Blueshifted Excursions" (RBEs; Langangen et al. 2008) have drawn much attention in recent years. Their rapid heating, high speed upflow and association with magnetic field indicate that the most possible underlying driving mechanism is magnetic reconnection on small scales. In order to understand the physical properties of these features, we carried out a coordinated high resolution and high cadence observation of chromospheric RBEs using the Interferometric BIdimensional Spectrometer (IBIS) at the Dunn Solar Telescope and photospheric magnetic fields using *Hinode* SOT/SP and SOT/NFI in October 2011. Different targets near disk center were observed, such as quite sun and active regions. For each target region, both Halpha and Ca II 854.2 nm lines were scanned by IBIS with high-spatial (~ 0.1 arcsec/pixel, with adaptive optics), high-temporal (~6s) and moderate-spectral (~0.1 angstrom) resolution. At the same time *Hinode*/SP and NFI pointing at the same area providing the geometry and time evolution of photospheric magnetic fields, such as flux emergence, convergence and cancellation on small spatial scales. We identify RBEs based on the IBIS observations, study their properties (velocity, density, temperature and statistical distribution) and search for signatures of small-scale magnetic reconnection in the *Hinode* magnetograms. The poster will show the details of the temporal and spatial relation between chromospheric RBEs and photospheric magnetic field activities.

References:

De Pontieu, B. et al. 2007, PASJ, 59, 655-662

Langangen, O. et al. 2008, ApJ, 679, L167

203.11 – **Detection of Solar Differential Rotation in Disk-Integrated Ca II K Measurements**

Luca Bertello[1], A. Pietarila[1], A. A. Pevtsov[1]

[1]*National Solar Observatory.*

9:00 AM - 6:30 PM

The characterization of solar differential rotation (SDR) from disk-integrated chromospheric measurements has important implications for the study of differential rotation and dynamo processes in other stars. Chromospheric lines, such as Ca II K, are very sensitive to the presence of activity on the disk and are an ideal choice for investigating SDR in Sun-as-a star

obervations. Here we use daily observations from the SOLIS Integrated Sunlight Spectrometer (ISS) to study the temporal variations of the Ca II K line profiles from 2006 to 2012.

We discuss the signature of SDR in the power spectra computed from time series of parameters derived from these profiles, and the implications for detecting differential rotation in other Main-Sequence stars.

203.12 – **Modeling Observed Characteristics of Chromospheric Evaporation Driven by Thermal Conduction Fronts from Reconnection**

Sean Brannon[1], D. Longcope[1]

[1]*Montana State University - Bozeman.*

9:00 AM - 6:30 PM

Recent observations of flaring loop footpoints have revealed the presence of both blueshifted and redshifted components to flare-heated chromospheric plasma, implying that the chromospheric anchors of the loop experience both upflows ("evaporation") and downflows ("condensation"). These observations also point to a transition temperature at which the flows switch from downward (redshift) to upward (blueshift), and show that this temperature is supercoronal. We present a 1D hydrodynamic model of a half-loop with a simplified three-region structure (chromosphere / transition region / corona) to study the characteristics of chromospheric evaporation and condensation. We use a hydrodynamic shock to create a thermal conduction front, which then propagates down the loop and heats the chromosphere. We use the results to calculate velocity-temperature profiles and differential emission measures, for several values of shock speed and chromosphere/corona temperature ratio. We also investigate the appearance of a large pressure peak that forms at the base of the transition region, and discuss the evaporation evolution in terms of this pressure peak. Finally, we discuss the physical mechanisms underlying the position and magnitude of the evaporation.

203.13 – **Theoretical Performance of a Multi-Order Spectral Imager for the Solar Transition Region**

Hans Courrier[1], C. Kankelborg[1]

[1]*Montana State University Physics.*

9:00 AM - 6:30 PM

The 2006 sounding rocket launch of the *Multi-Order Solar EUV Spectrograph (MOSES)* provided simultaneous imaging and spectroscopy of the solar atmosphere through the use of 3 projections provided by a concave reflection grating. A new, more flexible instrument design has been proposed that allows the use of 4-8+ projections to obtain higher moments of the spectral line profile in a configuration that also provides increased sensitivity and improved manufacturability. The optical performance of this instrument is investigated and optimized with respect to grating design parameters, and its scientific utility is discussed.

203.14 – **Joint Response of the Helium Lines to Chromospheric Heating in Solar-type Stars**

Mark S. Giampapa[1], V. Andretta[2], B. Beeck[3], A. Reiners[4], M. Schussler[3]

[1]*NSO,* [2]*INAF, Italy,* [3]*Max Planck Institute for Solar System Research, Germany,* [4]*Georg-August-Universitat, Germany.*

9:00 AM - 6:30 PM

We present a preliminary report on simultaneous observations of the He I 5876 and 10830 triplet lines, respectively, in a sample of solar-type stars. The near-IR spectra were obtained with the VLT and CRIRES instrument while the visible spectra were acquired with the MPG/ESO 2.2-m telescope in conjunction with the FEROS spectrograph. The correlation of the observed strengths of these lines will be examined and their potential as diagnostics of active region area coverage in solar-type stars will be discussed.

The NSO is operated by AURA under a cooperative agreement with the National Science Foundation.

203 – Chromosphere & Transition Region

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

203 – Chromosphere & Transition Region

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

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203 – Chromosphere & Transition Region

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

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204 – Solar Energetic Events & Flares

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

204.02 – **Simulating the Strength of the Neupert Effect in Large Flares**

Henry D. Winter, III[1], K. K. Reeves[1], A. Egan[2]

[1]SAO, [2]Bernard College.

9:00 AM - 6:30 PM

The Neupert Effect is the well known empirical result that the hard X-ray emission of about half of large, impulsive flares looks like the derivative of the soft X-ray emission. This relationship between the non-thermal, hard X-ray emission and the thermal, soft X-ray emission supports the theory that the majority of the energy liberated by the flare is in the form of non-thermal, high-energy electrons which then heat the thermal plasma and drive chromospheric evaporation. Observational estimates currently put the energy budget of a flare as ~75% in non-thermal processes and ~25% in thermal processes. However, the observational estimates of the thermal and non-thermal energy in flares are currently uncertain to within an order of magnitude. It is also unclear as to why ~24% of large, impulsive flares have their soft X-ray emission peak well before the end of the hard X-ray emission in direct violation of the Neupert Effect. In this work, we address the question of how non-thermal particle properties affect the observed Neupert Effect by simulating a series solar flares using the HyLoop code. HyLoop simulates non-thermal particles interacting a with thermal plasma and the thermal plasma's response to those interactions. A series of flares are simulated with different non-thermal particle parameters, such as pitch-angle distribution and non-thermal fraction of total flare energy. The hard and soft X-rays emissions are synthesized for each simulation. These simulated emissions are then used to determine what impacts the non-thermal particle parameters have on the observed Neupert Effect.

204.03 – **Simulating The Effects Of Turbulent Density Fluctuations On Solar Flare X-ray Spectrum**

Iain Hannah[1], E. P. Kontar[1], H. A. S. Reid[2]

[1]University of Glasgow, United Kingdom, [2]LESIA, Observatoire de Paris, France.

9:00 AM - 6:30 PM

The unprecedented RHESSI observations of solar flare hard X-rays (HXR) has forced us to consider mechanisms in addition to the traditional collisional view of coronal electron transport. The self-consistent generation of Langmuir waves by the electron beam is one such process, thought to be the source of the reverse drift decimetric radio emission seen in some flares. We have previously shown that the inclusion of Langmuir waves flattens the electron spectrum (Hannah et al. ApJ 2009) and produces a spectral index difference between the coronal and footpoint sources closer to observations (Hannah and Kontar A&A 2011). However the wave growth also results in fainter HXR emission requiring a higher flux of electrons to be accelerated, compounding the “number” problem. In this work we show that the addition of the interaction of the Langmuir waves with turbulent density fluctuations in the background plasma greatly alleviates this problem. We demonstrate the consequences of these self-consistent numerical simulations in the context of the observable HXR spectrum for a variety of forms of the density fluctuations.

204.04 – **The Energy-Dependent Growth Of RHESSI HXR Loops As A Possible Signature Of Turbulent Acceleration**

Iain Hannah[1], E. P. Kontar[1], N. L. S. Jeffrey[1]

[1]University of Glasgow, United Kingdom.

9:00 AM - 6:30 PM

Plasma turbulence is thought to be associated with various physical processes involved in solar flares, including magnetic reconnection, particle acceleration, and transport, though there is no direct observational basis. Using RHESSI observations and the hard X-ray (HXR) visibility analysis, we determine the spatial and spectral distributions of energetic electrons for a number of flares with HXR loops. The loop length and width is energy-dependent, its growth a signature of the transport of tens of keV electrons both along and across the guiding magnetic field of the loop. We show that the cross-field transport is consistent with the presence of magnetic turbulence in the loop, where electrons are accelerated, and estimate the magnitude of the field line diffusion coefficient for different phases of the flares. The relative energy density of magnetic fluctuations is calculated for given magnetic field correlation lengths and the level of the fluctuations is investigated as a function of the number of accelerated electrons for different phases of the flares. These HXR observations are consistent with the scenario that magnetic turbulence governs the evolution of energetic electrons in dense flaring loops and is suggestive of their turbulent acceleration.

204.05 – **Thermal Structure of Supra-Arcade Plasma in Two Solar Flares**

Kathy Reeves[1], S. L. Savage[2], D. E. McKenzie[3], M. A. Weber[1]

[1]Harvard-Smithsonian, CfA, [2]NASA Goddard/ORAU, [3]Montana State University.

9:00 AM - 6:30 PM

In this work, we use Hinode/XRT and SDO/AIA data to determine the thermal structure of supra-arcade plasma in two solar flares. The first flare is a M1.2 flare that occurred on November 5, 2010 on the east limb. This flare was one of a series of flares from AR 11121, published in Reeves & Golub (2011). The second flare is an X1.7 flare that occurred on January 27, 2012 on the west limb. This flare exhibits visible supra-arcade downflows (SADs), where the November 2010 flare does not. For these two flares we combine XRT and AIA data to calculate DEMs of each pixel in the supra-arcade plasma, giving insight into the temperature and density structures in the fan of plasma above the post-flare arcade. We find in each case that the supra-arcade plasma is around 10 MK, and there is a marked decrease in the emission measure in the SADs. We also compare the DEMs calculated with the combined AIA/XRT dataset to those calculated using AIA alone.

204.06 – **Abrupt Changes in the Photospheric Magnetic Structures and H-alpha Chromosphere during the 2006 December 6 X6.5 Flare**

Gordon Petrie[1], K. S. Balasubramaniam[2], O. Burtseva[1], A. A. Pevtsov[1]

[1]NSO, [2]Space Vehicles Directorate, Air Force Research Laboratory, Kirtland AFB.

9:00 AM - 6:30 PM

The active region NOAA 10930 produced the last X-class flares of Solar Cycle 23, including one at 18:29 UT on December 6. Here we investigate the relationships between signatures of this flare observed in the photospheric magnetic field and white light and continuum intensity, and H-alpha chromosphere. We use GONG 1-minute magnetograms and continuum intensity images and (1-minute?) ISOON white-light and H-alpha images to show that (1) the sunspot penumbral area and mean intensity decreased abruptly during the flare; (2) the magnetic field changed in large, contiguous patterns inside and immediately outside the southern and western penumbra resulting in a more vertical penumbral field on average; (3) H-alpha brightenings were observed to begin around the GOES start time, the earliest occurring near the sunspot and later brightenings progressively further north and south of the center of the active region near magnetic neutral lines; and (4) most of the detected photospheric flux cancellation (75%) occurred during the flare, and the remainder before the flare.

204.07 – **Nozzle Driven Shocks in Post-CME Plasma**

Roger B. Scott[1], D. W. Longcope[1], D. E. McKenzie[1]

[1]Montana State University.

9:00 AM - 6:30 PM

Models of patchy reconnection allow for heating and acceleration of plasma along reconnected field lines but do not offer a mechanism for transport of energy and momentum across field lines. Here we present a simple 2D model in which a localized region of reconnected flux creates an apparent constriction in the surrounding layer of unreconnected field. The moving constriction acts as a de Laval nozzle and ultimately leads to shocks which can extend out to several times the diameter of the flux tube, altering the density and temperature of the plasma in that region. These findings have direct implications for observations in the solar corona, particularly in regard to such phenomena as wakes seen behind supra-arcade downflows and high temperatures in post-CME current sheets. This work was supported by a joint grant from the NSF and DOE.

204.08 – **Return Current Energy Losses and Plasma Heating inSolar Flares**

Meriem Alaoui[1], G. Holman[1]

[1]GSFCNASA.

9:00 AM - 6:30 PM

High-energy electrons in solar flares are understood to be accelerated in the low corona and subsequently stream downward to the dense chromosphere where they are thermalized and emit X-rays. The current associated with these electrons is thought to be neutralized by a return current. This return current will heat the ambient plasma and the associated electric field will simultaneously decelerate the high-energy electrons.

I present numerical solutions to the equations for energy loss by return-current and Coulomb collisions in the solar atmosphere during a flare event. The injected electron beam is considered a power-law with a sharp low energy cutoff. I show the time evolution of the electron beam distribution throughout the one dimensional loop. Heating rates of the plasma due to return-currents and collisional heating by the higher-energy primary beam electrons are derived.

Three RHESSI flares that are good candidates for testing the numerical solutions are presented. These show evidence of flattening of the spectrum at lower energies, time evolution of the low-energy cutoff consistent with the model, and a return-current "bump" in X-ray light curves at low photon energies.

204.09 – **Physics of Transient Seismic Emission from Flares**

Charles A. Lindsey[1], A. Donea[2], A. Malanushenko[3]

[1]NorthWest Research Associates, [2]Monash University, Australia, [3]Lockheed-Martin Solar and Astrophysical Laboratory.

9:00 AM - 6:30 PM

We consider the physics of seismic activity in solar flares, i.e., the release of powerful seismic transients into the solar interior during the impulsive phases of some flares. Recent work by Hudson, Fisher, Welsch and Bercik has attracted a great deal of positive attention to the possible role of Lorentz-force transients in driving seismic transient emission in flares. The implications of direct involvement by magnetic forces in seismic transient emission, if this could be confirmed, would be major, since magnetic fields are thought to hold the energy source of the flares themselves. The energy invested into acoustic transients is a small fraction of the total released by the flare, but requires a massive impulse many times that required to accelerate high-energy electrons into which the energy is initially thought to be invested. What does this say about a flare mechanism that sometimes does both? We discuss some of the outstanding diagnostic questions that confront the recognition of magnetic-field transients associated with Lorentz force transients based on resources HMI, Hinode, AIA and other facilities offer us.

204.1 – **The Relationship Between Hard X-ray Pulse Timings and the Locations of Footpoint Sources During Solar Flares**

Andrew Inglis[1], B. Dennis[1]

[1]*NASA Goddard Space Flight Center.*
9:00 AM - 6:30 PM

The cause of quasi-periodic pulsations (QPP) in solar flares remains the subject of debate. Recently, Nakariakov & Zimovets (2011) proposed a new model suggesting that, in two-ribbon flares, such pulsations could be explained by propagating slow waves. These waves may travel obliquely to the magnetic field, reflect in the chromosphere and constructively interfere at a spatially separate site in the corona, leading to quasi-periodic reconnection events progressing along the flaring arcade. Such a slow wave regime would have certain observational characteristics. We search for evidence of this phenomenon during a selection of two-ribbon flares observed by RHESSI, SOHO and TRACE; the flares of 2002 November 9, 2005 January 19 and 2005 August 22. We were not able to observe a clear correlation between hard X-ray footpoint separations and pulse timings during these events. Also, the motion of hard X-ray footpoints is shown to be continuous within the observational error, whereas a discontinuous motion might be anticipated in the slow wave model. Finally, we find that for a preferential slow wave propagation angle of 25-28 degrees that is expected for the fastest waves, the velocities of the hard X-ray footpoints lead to estimated pulse periods and ribbon lengths significantly larger than the measured values. Hence, for the three events studied, we conclude that the observational characteristics cannot be easily explained via the Nakariakov & Zimovets (2011) propagating slow wave model when only angles of 25-28 degrees are considered. We provide suggested flare parameters to optimise future studies of this kind.

204.11 – **A Comprehensive View of the Temperature Distribution in Solar Flares from EVE and RHESSI**

Amir Caspi[1], J. M. McTiernan[2], H. P. Warren[3]

[1]*Laboratory for Atmospheric and Space Physics, Univ. of CO, Boulder,* [2]*Space Sciences Laboratory, Univ. of CA, Berkeley,* [3]*Naval Research Laboratory.*
9:00 AM - 6:30 PM

Solar flares accelerate electrons up to hundreds of MeV and heat plasma up to tens of MK, but the physical processes behind these phenomena remain poorly understood. While the ubiquitous ~10-25 MK plasma is commonly accepted to result from chromospheric evaporation, evidence suggests that in intense (GOES M- and X-class) flares, the hottest, ~20-50 MK plasma is directly heated in the corona, although the heating mechanism and its connection to the flare-accelerated non-thermal electrons is not yet understood. While observations of hard X-ray bremmstrahlung directly probe the non-thermal electron population, the spectra below ~20-30 keV are typically dominated by strong thermal emission. The low-energy extent of the non-thermal spectrum can thus be only loosely quantified, which has significant implications for calculating flare energy budgets and for constraining possible acceleration mechanisms. Hence, a precise characterization of the thermal electron population is imperative.

New extreme ultraviolet observations from the EUV Variability Experiment (EVE) on-board the Solar Dynamics Observatory (SDO), combined with X-ray data from the Reuven Ramaty High Energy Spectroscopic Imager (RHESSI), offer the most comprehensive view into the flare temperature distribution to date. EVE observes a wealth of EUV emission lines with peak formation temperatures of ~2-20 MK, while RHESSI observes the X-ray bremsstrahlung of hot, ~10-50 MK plasmas; combined, the two instruments have excellent temperature sampling and coverage over the full range of flare plasma temperatures. We have calculated differential emission measures (DEMs) using EVE and RHESSI independently, for separately observed events. We present a novel method of combining simultaneous EVE and RHESSI observations to determine the flare DEM, and its evolution, over the full ~1-100 MK range during intense M/X flares. We present preliminary results from the 2011-Feb-15 X2.2 flare, and compare with the RHESSI non-thermal emission to discuss the implications for flare plasma heating.

204.12 – **Direct Comparison Of A Moreton Wave, EUV Wave And CME**

Stephen M. White[1], E. Cliver[1], K. Balasubramaniam[1]

[1]*Air Force Research Laboratory.*
9:00 AM - 6:30 PM

The first period of major solar activity in the current cycle, due to AR 11158 in mid February 2011, produced a sequence of solar flares exhibiting both Moreton waves in H-alpha images and "EIT-waves" seen in EUV images. Given the rarity of Moreton waves, this offers an excellent opportunity to compare the properties of the two phenomena with simultaneous observations. We focus on the event of 17:24 UT on February 14, which was well-observed by a number of observatories. We find a strong link between the Moreton wave, the EUV wave and the CME in this event. The Moreton wave has the same speed as the EUV wave, but it lags behind the leading edge of the EUV wave. A vertical signature is seen in the H-alpha Doppler images. STEREO observations of the CME indicate that initially the vertical speed of the disturbance was not as high as the EUV wave speed, and the CME rapidly decelerates on merging with a rising loop system. We interpret the results in light of current models for such disturbances.

204.13 – **Characteristic Size Of Flare Kernels In Visible And The Near-infrared Continua**

Yan Xu[1], W. Cao[1], J. Jing[1], H. Wang[1]

[1]*New Jersey Institute of Tech..*
9:00 AM - 6:30 PM

In this study, we present a new approach to estimate the formation height of visible and the near-infrared emission during an X10 flare. The sizes of flare cores in three wavelengths are accurately measured during the peak time. The result shows that the source size is the largest in G-band at 4308 Å and shrinks towards longer wavelengths, namely the green continuum at 5200 Å and NIR at 15600 Å, where the emission is believed to originate from deeper atmosphere. This size-wavelength variation is likely explained by the direct heating model as electrons need to move along converging field lines. In this model, energetic electrons are confined by the magnetic field lines, which converge from the corona to the photosphere. Therefore one can observe the smallest source, which in our case is 0.65 ± 0".02 (radius by assuming a circular shape) in the bottom layer (represented by NIR) and observe relatively large kernels in upper layers of 1".03 ± 0".14 and 1".96 ± 0".27, using the green continuum and G-band respectively. We then compare the source sizes with a simple magnetic geometry to derived the formation height of the white-light sources and magnetic pressure in different layers inside the flare loop.

204.14 – **Flare-associated Energy Exchange Between the Photosphere and Corona**

Valentyna Abramenko[1], L. Harra[2]

[1]*Big Bear Solar Observatory,* [2]*UCL-Mullard Space Science Laboratory, Holmbury St Mary, United Kingdom.*
9:00 AM - 6:30 PM

In recent decades, it has been clearly demonstrated that strong flares in ARs (referred before as chromospheric flares) are not restricted to some closed volume in the chromosphere but rather involve a huge volume from deep sub-photospheric layers to the outer heliosphere. Undoubtedly, there exists interaction and energy exchange between different parts of the volume occupied by a flare, e.g., reconnection between up-welling loops and the pre-existing flux, waves and shocks, seismic response to a flare, momentum distribution and Lorentz Force acting, accelerated particle, heat, X-ray propagation, Poynting flux transport, etc. However, mechanisms of the processes, as well as their relationship with the flare itself (is a phenomenon a prelude to the flare, its consequence or non of such) is not well understood yet. We explore new metrics of the photospheric magnetic field: we monitor the magnetic energy dissipation rate. For three strong flares, we found that the magnetic energy dissipation rate sets to a monotonous ceasing several hours before the flare onset. Assuming nearly gradual energy input, the reduction of the energy dissipation rate implies that somewhere in the active region, the energy is being accumulated. The non-dissipated and accumulated energy amounts to (3 - 10) x 10^{32} ergs. We presume that at least part of the energy accumulated immediately before the flare is transferred into the corona and further drives the corona to a trigger point when flare occurs.

204.15 – **Temperature Evolution Before Flare Events for Active Regions at the Limb**

Andrew P. Sturner[1], K. Korreck[2]

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

We investigate the spatial and temporal evolution for active regions at the limb immediately before the onset of a flare, using SDO/AIA images. We compare the shape and time delay between light curves in the six EUV filters, and then analyze the evolution of the emission-measure weighted temperature. Understanding this evolution is necessary for evaluating flare heating models used in space weather prediction algorithms.

204.16 – **New Statistical Approaches to RHESSI Solar Flare Imaging**

Richard A. Schwartz[1], F. Benevenuto[2], A. Massone[3], M. Piana[2], A. Sorrentino[4]

[1]*NASA's GSFC,* [2]*dipartimento di matematica, università di genova, Italy,* [3]*CNR SPIN, Italy,* [4]*department of statistics, United Kingdom.*
9:00 AM - 6:30 PM

We present two statistical approaches to image reconstruction from RHESSI measurements. The first approach implements maximum likelihood by means of an expectation-maximization algorithm resembling the Lucy-Richardson method. The second approach is genuinely Bayesian in the fact that it introduces the use of a prior probability distribution coding information known a priori on the flaring source. The posterior distribution is computed by means of an importance sampling Monte Carlo technique. Further, this approach will be extended to a filtering method in which the posterior distribution at a specific energy or time interval is used as a prior for the next interval. Finally, we will also study the possibility to adapt this method to multi-scaling reconstruction exploiting the different resolution powers provided by the nine RHESSI collimators.

204.17 – **On the Origin of Solar Flare's EUV Late Phase**

Kai Liu[1], J. Zhang[1], Y. Wang[2], X. Cheng[3]

[1]*GMU,* [2]*USTC, China,* [3]*NJU, China.*

9:00 AM - 6:30 PM

It has been well known that a solar flare typically has an impulsive phase, or the main energy release phase, immediately followed by a gradual phase or decay phase as best seen in soft X-ray emissions. A recent discovery based on EUV Variability Experiment (EVE) observations onboard Solar Dynamics Observatory (SDO) reveals that many flares exhibit a second large peak separated from the primary flare event by many minutes to hours; this second peak is coined as the flare's EUV late phase (Woods et al. 2011). The EUV late phase is most evident in warm coronal emissions (e.g., Fe XVI 33.5 nm). In this Letter, we explore the origin of the EUV late phase through analyzing in detail two late phase flares, M2.9 flare on 2010 October 16 and M1.4 flare on 2011 February 18, using multi-passband imaging observations from Atmospheric Imaing Assembly (AIA) onboard SDO. We find that: (1) the late phase emissions originate from a different magnetic flux system from the main phase flare loop arcade. (2) The two flux systems are magnetically connected in topology, i.e., they share one common polarity magnetic region for one of their two footpoints. (3) The late phase loop arcade appears progressively in time from high to low temperatures, while the main phase arcade reaches the peak at almost the same time for all coronal temperatures. (4) The brightening of the isolated footpoint ribbon of late phase arcade is always tens of seconds later than the main phase ribbons. These results suggest that the late phase EUV emission, while originates from a different magnetic flux system, is possibly triggered by the eruption of the main phase flare through the interconnection of the two magnetic flux systems.

204.18 – **Using HMI To Study Photospheric Footpoint Motions In X-class Flares**

Priyamvada Desai[1], R. Bogart[1], S. Couvidat[1], J. Schou[1]

[1]*Stanford University.*

9:00 AM - 6:30 PM

Recent investigations of flare-related changes in the photospheric absorption line (FeI 617.3 nm) profile of solar flares of varying X-ray classes, observed using the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamic Observatory (SD0), has indicated that a large percentage of them show distinct continuum enhancement, along with a marked decrease in line-depth (Desai,et al,submitted).

Some of the X-class flares also showed a reversal in the line profile, from absorption into emission during the peak of the flare. We investigate the temporal and spatial variations in the velocity of the photospheric foot point motions and track the evolution of the flares of some of these X-class flares.

204.19 – **Coupling of Particle Acceleration and Atmospheric Dynamic Response to Impulsive Energy Release in Solar Flares**

Wei Liu[1], V. Petrosian[2], Q. Chen[2], J. Mariska[3]

[1]*Stanford-Lockheed Institute for Space Research,* [2]*Stanford University,* [3]*George Mason University.*

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In solar flares, acceleration and transport of high-energy particles and fluid dynamics of the atmospheric plasma are interrelated processes coupled in a circular chain. Chromospheric evaporation, for example, can alter the density and temperature distribution along the flare loop, in particular in the acceleration site near the loop-top source. This produces a feedback on particle collisional heating, and more importantly on the energy release and acceleration process. This in turn will change the heating of the chromosphere and mass flows in the corona. In recent years, there have been increasing theoretical and observational motivations to investigate these coupled processes together in a self-consistent manner. We present here combined Fokker-Planck modeling of particles and hydrodynamic simulation of flare plasma. We extended our earlier hybrid simulation (Liu, Petrosian, Mariska 2009) by feeding the updated plasma density and temperature at the loop-top source to the stochastic acceleration process. We find that the density enhancement causes the ratio of the electron plasma frequency to gyro-frequency to increase. This can lead to the reduction of the efficiency of electron acceleration and thus the quenching or spectral softening of nonthermal hard X-ray tails observed during the late stages of flares. This also affects the relative production of energetic electrons vs. protons (Petrosian and Liu 2004). We will compare our results with recent observations from RHESSI, SDO, and Hinode. We will also discuss their implications for cyclic spectral hardening, quasi-periodic flare pulsations, and recently imaged super-fast quasi-periodic coronal waves originating from flare kernels.

204.21 – **EUV Rapid Cadence Spectroscopic Observation of Direct Coronal Heating During a C-class Solar Flare**

Jeffrey W. Brosius[1]

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9:00 AM - 6:30 PM

With CDS operating in rapid cadence (9.8 s) stare mode during a C6.6 flare on the solar disk, we observed a sudden brightening of Fe XIX line emission (formed at temperature around 8 MK) above the pre-flare noise without a corresponding brightening of emission from ions formed at lower temperatures, including He I (0.01 MK), O V (0.25 MK), and Si XII (2 MK). The sudden brightening persisted as a plateau of Fe XIX intensity that endured more than 11 minutes. The Fe XIX emission at the rise and during the life of the plateau showed no evidence of significant bulk velocity flows, and hence cannot be attributed to chromospheric evaporation. However, the line width showed a significant broadening at the rise of the plateau, corresponding to nonthermal velocities of at least 89 km/s due to reconnection outflows or turbulence. During the plateau He I, O V, and Si XII brightened at successively later times starting about 3.5 minutes after Fe XIX, which suggests that these brightenings were produced by thermal conduction from the plasma producing Fe XIX line emission; however, we cannot rule out the possibility that they were produced by a weak beam of nonthermal particles. O V showed an upward velocity around -10 km/s for about 2 minutes toward the middle of the plateau, indicating gentle chromospheric evaporation.

This work is supported by NASA grant NNX10AC08G.

204.22 – **Complex Dynamic Flows in Solar Flare Sheet Structures**

David Eugene McKenzie[1], K. K. Reeves[2], S. L. Savage[3]

[1]*Montana State Univ.,* [2]*Harvard-Smithsonian Astrophysical Observatory,* [3]*NASA/GSFC (ORAU).*

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Observations of high-energy emission from solar flares often reveal the presence of large sheet-like structures, sometimes extending over a space comparable to the Sun's radius. Given that these structures are found between a departing coronal mass ejection and the post-eruption flare arcade, it is natural to associate the structure with a current sheet; though the relationship is unclear. Moreover, recent high-resolution observations have begun to reveal that the motions in this region are highly complex, including reconnection outflows, oscillations, and apparent wakes and eddies. We present a detailed first look at the complicated dynamics within this supra-arcade plasma, and consider implications for the interrelationship between the plasma and its embedded magnetic field.

This work is supported by NASA under contract SP02H3901R from Lockheed-Martin to MSU (DMcK), contract SP02H1701R from Lockheed-Martin to SAO (KKR), and contract NNM07AB07C with the Harvard-Smithsonian Astrophysical Observatory. SLS is supported via a NASA/GSFC NPP appointment administered by Oak Ridge Associated Universities and under the mentorship of G. Holman.

204.23 – **Efficiency Of Energy Dissipation At A Magnetic X-point**

Dana Longcope[1], L. Tarr[1]

[1]*Montana State Univ..*

9:00 AM - 6:30 PM

Magnetic reconnection at a current sheet is believed to release stored magnetic energy by decreasing the net current carried by the sheet. The current change will affect magnetic field throughout the coronal volume, not just on field lines transferred across the current sheet. This global effect results from a fast magnetosonic rarefaction wave launched by the reconnection, which carries away the excess current and converts free magnetic energy to kinetic energy through the volume. The present work demonstrates, in a simplified model, how reflection of this wave from the photospheric boundary determines the total energy dissipation possible. Previous investigations by Craig and McClymont (1991) and Hassam (1992) assumed one-hundred percent of the reflected wave returned to the dissipation region (the X-point), and thereby concluded that all of the stored energy could be dissipated eventually. The present investigation uses a more realistic geometry to show that only a fraction of the stored magnetic energy could be directly dissipated, at least within the dissipation region. The remaining energy continues to propagate as a fast magnetosonic wave.

204.24 – **RHESSI X-ray Detection of Thermal Footpoint Emission down to 3 keV in an X1.9 Solar Flare**

Qingrong Chen[1], V. Petrosian[1]

[1]*Stanford University.*

9:00 AM - 6:30 PM

We present for the first time distinct detection of impulsive thermal X-ray emission from the footpoint (FP) regions of a flaring loop down to 3 keV by RHESSI in an X1.9 class solar flare on 2011 September 24. RHESSI imaging observation of the flare shows three well-separated X-ray sources, two FP sources from 3 keV to 300 keV and a coronal loop top (LT) source from 3 keV to 50 keV. Preliminary imaging spectroscopic analysis indicate that at ~3-15 keV both the LT and the summed FP spectra are dominated by comparable thermal emission (T ~ 1.5 keV, EM ~ 10^49 cm^-3), while at higher energies the spectra are nonthermal; and the column density from the LT to the FP is found to be at least 10^20 cm^-2. Existence of ~3 keV thermal FP sources in this flare cannot be easily explained by current theoretical models, in particular, the collisional transport model. We will present detailed observations of the flare from RHESSI and SDO and discuss possible electron acceleration and transport scenarios that may account for the observed low-energy thermal FP emission.

204.25 – **Accelerated Electron Spectra and Turbulence Characteristics from RHESSI Solar Flare Observations II**

Qingrong Chen[1], V. Petrosian[1]

[1]*Stanford University.*

9:00 AM - 6:30 PM

We present our recent progress since the 2011 SPD meeting on understanding electron acceleration from RHESSI imaging spectroscopic observations of solar flares. In our earlier work, based on electron spectra at the loop top (LT) and footpoints (FPs) obtained from the regularized electron flux images, we have determined the accelerated electron spectrum at the coronal acceleration region,

derived the electron escape time and pitch-angle scattering time due to an agent other than Coulomb collisions, presumably plasma waves or turbulence, and obtained the direct acceleration time by a forward fitting procedure. Here, by the aid of the steady-state Fokker-Planck equation, we further derive the formulae for the energy dependence of energy diffusion time and direct acceleration time, assuming their relation to be described by the model of stochastic acceleration by turbulence. Thus we are now in a position where we can uniquely and non-parametrically determine the energy dependence of all the relevant timescales (or rates) responsible for the electron pitch-angle scattering, acceleration, and escape processes in the acceleration region. This provides a new perspective in directly constraining electron acceleration models in solar flares. For a few RHESSI flares, we find that the inversion results of the acceleration timescale are comparable to the conventional forward fitting results. We also show that the same formalism can be easily applied to hard X-ray spectra at the LT and FPs when the electron images are unavailable.

204.26 – **Non-Linear Force Free Field Modeling and Flare Ribbon Comparison of AR11347**

Sean McKillop[1], A. Savcheva[2]

[1]Smithsonian Astrophysical Observatory, [2]Boston University.

9:00 AM - 6:30 PM

In this project we present a model of active region (AR) 11347. This region was observed on November 15, 2011 with the Atmospheric Imaging Assembly (AIA) aboard the Solar Dynamics Observatory (SDO). The region produced a small flare around 17:00 UT on that date. We build a Non-Linear Force Free Field (NLFFF) model of the AR via the flux-rope insertion method, using Helioseismic and Magnetic Imager (HMI) magnetograms as the boundary condition and AIA coronal observations as the constraint on the models. The observed loops in the core of the region are clearly sheared and twisted. For the best-fit model we compute the Quasi-Separatrix Layers (QSL) throughout the volume and compare the QSLs in the low corona with the flare ribbons as seen in AIA data.

204.27 – **Heating of Flare Foops During a Two-ribbon Flare on 2011 March 07**

Wenjuan Liu[1], J. O'Hara[2], C. Peck[1], J. Qiu[1], D. W. Longcope[1]

[1]Montana State University, [2]University of St Andrews, United Kingdom.

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Recent observations have revealed that flare loops are formed and heated by reconnection events taking place successively. This is evident in high-resolution EUV observations of post-flare loops, as well as the apparent "motion" of UV bright kernels outlining the feet of these loops. Our recent study shows that the spatially resolved UV brightness at the foot-points of individual loops grows rapidly on timescales of a few minutes, followed by a long decay on timescales of tens of minutes. This distinctive two-phase pattern of the UV light curve represents the impulsive energy deposition during the rapid rise and the subsequent hydrodynamic plasma evolution in the coronal loop during the gradual decay. In this study, we analyze an M-class flare observed by AIA. We utilize the spatially resolved UV brightness time profiles to infer impulsive heating functions of a few thousand flux tubes anchored at the UV foot-points, and compute plasma evolution in each flux tube using the EBTEL model (Klimchuk et al. 2008). The coronal radiation is then calculated and compared with soft X-ray and EUV light curves observed by GOES and AIA. With a steady-state assumption, we also compute the transition-region DEM for each flux tube during its decay phase, and compare the predicted optically-thin transition-region line (C IV) emission with the observation. This study presents a method to infer heating functions of reconnection formed flare loops and how they affect evolution of the overlying corona as well as the lower-atmosphere dynamics coherently.

204.28 – **Uncertainty Estimation in Fitting Parameterized Models to Solar Flare Hard X-ray Spectra**

Jack Ireland[1], A. K. Tolbert[2], G. D. Holman[3], B. R. Dennis[3], R. A. Schwartz[2]

[1]ADNET Systems, NASA's GSFC, [2]Catholic University of America, [3]NASA GSFC.

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We compare four different methods of estimating the uncertainty in fit parameters when fitting models to Ramaty High Energy Solar Spectroscopic Imager (RHESSI) spectral data. Two flare spectra are studied: one from the GOES (Geostationary Operational Environmental Satellite) X1.3 class flare of 19-January-2005, and the other from the X4.8 flare of 23-July-2002. Three of our methods rely on assumptions about the shape of the hyper-surface formed by the weighted sum of the squares of the differences between the model fit and the data as a function of the fit parameters, evaluated around the minimum value of the hyper-surface, to generate uncertainty estimates. The fourth method is based on Bayesian data analysis

techniques.

The four methods give approximately equal uncertainty estimates for the 19-January-2005 model parameters, but give very different uncertainty estimates for the 23-July-2002 model parameters. This is because the assumptions required for the first three methods hold approximately for the 19-January-2005 analysis, but do not hold for the 23-July-2002 analysis. The Bayesian-based method does not require these assumptions, and so can give reliable uncertainty estimates regardless of the shape of the hyper-surface formed by the model fit to the data. We show that for the 23-July-2002 spectrum, there is a 95% probability that the low energy cutoff to the model distribution of emitting flare electrons lies below approximately 40keV, and a 68% probability that it lies in the estimated range 7-36 keV. The most probable flare electron energy flux is approximately $10^{28.1}$ $erg^{-1}sec^{-1}$ with a 68% credible interval estimated at $10^{28.1\text{-}29.1}$ $erg^{-1}sec^{-1}$, and a 95% credible interval estimated at $10^{28.0\text{-}30.3}$ $erg^{-1}sec^{-1}$. For the 19-January-2005 spectrum, these quantities are more tightly constrained to 105±4 keV and $10^{27.66\pm0.01}$ $erg^{-1}sec^{-1}$ (68% uncertainties). The reasons for these disparate results are discussed.

This work is funded by the NASA Solar and Heliospheric Physics program.

204.29 – **Irreversible Change of Photospheric Magnetic Field: Evidence for Back Reaction of Coronal Field Restructuring**

Shuo Wang[1], C. Liu[1], R. Liu[1], N. Deng[1], Y. Liu[2], H. Wang[1]

[1]Space Weather Research Laboratory, New Jersey Institute of Technology, [2]W. W. Hansen Experimental Physics Laboratory, Stanford University.

9:00 AM - 6:30 PM

It is well known that the long-term evolution of the photospheric magnetic field plays an important role in building up free energy to power solar eruptions. Observations, despite being controversial, have also revealed a flare-related, rapid and permanent variation of the photospheric magnetic field. In this study, we use the unprecedented data from the Helioseismic and Magnetic Imager to analyze several flare events with different GOES-class and disk position. For the 2011 February 15 X2.2 flare where 12 minute cadence vector magnetograms are available, we obtained the first solid evidence of a rapid (in about 30 minutes) and irreversible enhancement in the horizontal magnetic field at the flaring magnetic polarity inversion line (PIL) by a magnitude of ~30%. It is also shown that the photospheric field becomes more sheared and more inclined. This field evolution is unequivocally associated with the flare occurrence in this sigmoidal active region, with the enhancement area located in between the two chromospheric flare ribbons and the initial conjugate hard X-ray footpoints. The spatial distribution of the Lorentz-force changes within the entire active region is further analyzed. We also discuss other events using the LOS magnetograms with 45 s cadence. A consistent pattern is revealed, in which the observed limbward flux increases while the diskward flux decreases rapidly and irreversibly after flares. These results strongly corroborate our previous conjecture that the photospheric magnetic field near the PIL must become more horizontal after eruptions, in response to the back reaction of coronal magnetic field restructuring during eruptions.

204.3 – **Expanded Owens Valley Solar Array (EOVSA) Testbed and Prototype**

Dale E. Gary[1], G. M. Nita[1], N. Sane[1]

[1]NJIT.

9:00 AM - 6:30 PM

NJIT is engaged in constructing a new solar-dedicated radio array, the Expanded Owens Valley Solar Array (EOVSA), which is slated for completion in late 2013. An initial 3-antenna array, the EOVSA Subsystem Testbed (EST), is now in operation from 1-9 GHz based on three of the old OVSA antennas, to test certain design elements of the new array. We describe this instrument and show some results from recent solar flares observed with it. We also describe plans for an upcoming prototype of EOVSA, which will use three antennas of the new design over the full 1-18 GHz signal chain of the entirely new system. The EOVSA prototype will be in operation by late 2012. Highlights of the new design are ability to cover the entire 1-18 GHz in less than 1 s, simultaneous dual polarization, and improved sensitivity and stability. We discuss what can be expected from the prototype, and how it will compare with the full 13-antenna EOVSA. This work was supported by NSF grants AGS-0961867 and AST-0908344, and NASA grant NNX11AB49G to New Jersey Institute of Technology.

204.31 – **Multi-Stranded Coronal Loops - A Statistical Forward Model**

Adam Kobelski[1], D. E. McKenzie[1]

[1]Montana State University.

9:00 AM - 6:30 PM

Strong evidence currently exists that coronal loops as observed in EUVs and soft X-rays are not monolithic structures, but actually exist as bundles of independent strands. It is of significant importance to determine the size and number density of these strands in order to better understand the spatial and temporal scales of magnetic reconnection in the corona. In order to empirically estimate these parameters, we have developed software to forward model the cooling of flaring loops as bundles of strands in order to estimate their observational signatures. By applying this forward model to a large database of flares observed by Yohkoh/SXT, we employ a statistical analysis to constrain the parameters in flaring coronal plasma. Results of this analysis will be presented.

204.32 – **Calculating Separate Magnetic Free Energy Estimates for Active Regions Producing Multiple Flares: NOAA AR11158**

Lucas Tarr[1], D. W. Longcope[1]

[1]Montana State University.

9:00 AM - 6:30 PM

It is well known that photospheric flux emergence is an important process for stressing coronal fields and generating magnetic free energy, which may then be released during a flare. The Helioseismic and Magnetic Imager(HMI) onboard the Solar Dynamics Observatory (SDO) captured the entire emergence of NOAA AR 11158. This region emerged as two distinct bipoles, possibly connected underneath the photosphere, yet characterized by different photospheric field evolutions and fluxes. The combined active region complex produced 15 GOES C-class, 2 M-class, and the X2.2 Valentine's Day Flare during the four days after initial emergence on February 12th, 2011. The M and X class flares are of particular interest because they are nonhomologous, involving different subregions of the active region. We use a Magnetic Charge Topology together with the Minimum Current Corona model of the coronal field to model field evolution of the complex. Combining this

with observations of flare ribbons in the 1600 Angstrom channel of the Atmospheric Imaging Assembly (AIA) onboard SDO, we generate a separate energy estimate for each major flare using their respective unique subsets of stressed magnetic domains. This work is supported under contract SP02H3901R from Lockheed-Martin to MSU.

204.33 – **Magnetic Footprints Of Flares**

Olga Burtseva[1], J. C. Martinez-Oliveros[2], G. Petrie[1]

[1]National Solar Observatory, [2]SSL, University of California Berkeley.

9:00 AM - 6:30 PM

The chromospheric hard X-ray (HXR) emission in solar flares is generally regarded as the footprints of magnetic field lines newly reconnected in the corona. Also, the footpoint motions away from the neutral line are considered to be indicative of the reconnection occurring in different heights of arcade magnetic fields with a displacement speed proportional to the reconnection rate. We compare abrupt permanent magnetic field changes observed by GONG and HMI instruments during strong flares with location of the HXR flare footpoints obtained by RHESSI to relate the field changes to the reconnection processes in the corona and investigate the origin of the field changes. First results show good spatial and temporal correlation between the longitudinal field changes during flare and HXR emission. We do a correlative study of the intensity of both datasets and compare changes in the magnetic field with the location and evolution of flare footpoints.

204.34 – **Do Type III-associated Escaping Electron Beams Cool The Corona?**

Pascal Saint-Hilaire[1], L. Wang[1], S. D. Christe[2], N. Vilmer[3], A. Kerdraon[3], R. P. Lin[1]

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A recent study of decimetric Type III radio burst emission from data from the Nancay Radio Heliograph (NRH) will be presented. It examined sizes, locations, and fluxes of close to 10'000 decimetric Type III bursts. The flux study suggests that electron beams related to Type III emission could be responsible for carrying energy away from the corona in a proportion similar to that of EUV nanoflare heating. This tentative conclusion was reached from comparing Type III dN/dS distributions to the dN/dS of EUV/SXR nano-/micro-flares. The biggest uncertainty is the radiative efficiency, i.e. the ratio of radiated energy in decimetric Type III bursts and the energy of the electrons in the beams associated with them. We will constrain this value through other, new observations: we have already computed the amount of Type III radiated energy from NRH observations, and we will now compare them with the amount of energy in the corresponding beam electron detected in-situ by the Wind spacecraft. Given our sample of close to 10'000 decimetric Type IIIs, we expect a decent amount of in-situ beam energy estimates from magnetically connected events. Moreover, we will compare with X-ray-derived energies from corresponding RHESSI (micro)flares, when such an association exists.

204.35 – **Identification of Backside Solar Proton Events**

Jinhye Park[1], Y. Moon[1]

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9:00 AM - 6:30 PM

Solar proton events (SPEs) are defined as those having a flux of 10 particles $cm^{-2}sec^{-1}ster^{-1}$ in the > 10MeV energy channel. The NOAA SPE list from 1997 to 2011 shows that most SPEs are related to both flares and CMEs. However, seven events are related to only CMEs and seven events do not have enough flare information. In this study, we carefully identify the sources of these events.

First, we examine the directions of CMEs related to the events. Second, we search for major active regions (ARs) in the front solar disk for several days before the occurrences of the SPEs. As a result, we are able to determine ARs which are likely to produce SPEs as well as their longitudes at the times of SPEs by considering solar rotation rate. From this study, we find that the longitudes of 10 ARs are located behind the west limb, 2 ARs are located behind the east limb, and 2 ARs are located near west limb. For the confirmation of the SPE source location, it is found that the SPE flux profiles of these events are consistent with the typical ones from all SPEs. Also, we verify that our estimation (W127) of a SPE source region on 21 March 2011 is quiet consistent with the independent direct estimation (W131) by the STEREO/EUVI images. Our results imply that SPEs without enough flare information are mostly caused by backside events and suggest a possibility that nearly all SPEs are associated with both flares and CMEs. Also, it is noticeable that about 11% (12/106) of the SPEs from 1997 to 2011 are the backside SPEs.

204.36 – **A Comparison of Solar Energetic Particle Events with 1 AU Magnetic Field Connections to Solar Coronal Holes**

Stephen W. Kahler[1], C. N. Arge[1], S. Akiyama[2], N. Gopalswamy[3]

[1]Air Force Research Laboratory, [2]The Catholic University of America, [3]NASA Goddard Space Flight Center.

9:00 AM - 6:30 PM

The observed properties of solar energetic particle (SEP) events are known to depend on the source locations and speeds of their associated coronal mass ejections (CMEs). However, the CME characteristics cannot account for a great deal of the variability in SEP event intensities and time scales. It has long been suspected that the presence of coronal holes (CHs) near the CMEs or near the 1 AU magnetic footpoints may be an important factor in SEP events. We use a group of E ~20 MeV SEP events with origins near solar central meridian to look for possible CH effects. The CH connections from 1 AU are determined from the 4-day forecast maps based on Mount Wilson Observatory and the National Solar Observatory synoptic magnetic field maps and the Wang-Sheeley-Arge model of solar wind propagation. The observed in situ magnetic field polarities and solar wind speeds at SEP event onsets test the forecast accuracies to select the best SEP/CH connection events for analysis. The SEP event properties are then compared with the relative locations and separations of the CMEs and the 1 AU footpoints to determine whether and how the CHs may affect SEP events.

204.37 – **Empirical Determination of the Energy Loss Rate of Accelerated Electrons in a Well-Observed Solar Flare**

A. Gordon Emslie[1], G. Torre[2], N. Pinamonti[2], J. Guo[2], A. M. Massone[3], M. Piana[2]

[1]Western Kentucky University, [2]University of Genoa, Italy, [3]CNR, Italy.

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We present electron images of an extended solar flare source, deduced from RHESSI hard X-ray imaging spectroscopy data. We apply the electron continuity equation to these maps in order to determine empirically the form of the energy loss rate for the bremsstrahlung-emitting electrons. We show that this form is consistent with an energy transport model involving Coulomb collisions in a target with a temperature of about 2×10^7 K, with a continuous injection of fresh deka-keV electrons at a rate of approximately 10^{-2} electrons s^{-1} per ambient electron.

204.38 – **The Limit of Magnetic-Shear Energy in Solar Active Regions**

Ronald L. Moore[1], D. A. Falconer[1], A. C. Sterling[1]

[1]NASA's MSFC.

9:00 AM - 6:30 PM

It has been found previously, by measuring from active-region magnetograms a proxy of the free energy in the active region's magnetic field, (1) that there is a sharp upper limit to the free energy the field can hold that increases with the amount of magnetic field in the active region, the active region's magnetic flux content, and (2) that most active regions are near this limit when their field explodes in a CME/flare eruption. That is, explosive active regions are concentrated in a main-sequence path bordering the free-energy-limit line in (flux content, free-energy proxy) phase space. Here we present evidence that specifies the underlying magnetic condition that gives rise to the free-energy limit and the accompanying main sequence of explosive active regions. Using a suitable free energy proxy measured from vector magnetograms of 44 active regions, we find evidence that (1) in active regions at and near their free-energy limit, the ratio of magnetic-shear free energy to the non-free magnetic energy the potential field would have is of order 1 in the core field, the field rooted along the neutral line, and (2) this ratio is progressively less in active regions progressively farther below their free-energy limit. Evidently, most active regions in which this core-field energy ratio is much less than 1 cannot be triggered to explode; as this ratio approaches 1, most active regions become capable of exploding; and when this ratio is 1, most active regions are compelled to explode.

This work was funded by NASA's Science Mission Directorate through the Heliophysics Guest Investigators Program, the *Hinode* Project, and the Living With a Star Targeted Research & Technology Program.

204.39 – **Modeling of Magnetic Non-Potentiality of Active Region using a 3D Data-Driven Active Region Evolution Model: Seeking Necessary and Sufficient Conditions for Solar Eruption**

S. T. Wu[1], D. Falconer[1], Q. Hu[1], A. Wang[1], G. A. Gary[1]

[1]Univ. of Alabama, Huntsville.

9:00 AM - 6:30 PM

One of the major interesting problems for space weather forecasting is to have the capability of predicting solar eruptive events. To achieve this goal, we must investigate the evolution of an Active Region. In this presentation, we will present an investigation of the magnetic field structures for two productive Active Regions using a data-driven 3D MHD model: AR 10720 of Jan 15, 2005, where the measured magnetic field from Big Bear Solar Observatory (BBSO) digital vector magnetogram (DGVM) was used and (ii) AR11117 of October 25, 2010 where the vector magnetic field are measured by SDO/HMI. The numerical results include the change of magnetic flux, the net electric current, the length of magnetic shear of the main neutral line, and the flux normalized measure of the field twist. From these results we found the above four non-potential magnetic parameters increase and decrease before and after solar eruption. In other words, these four parameters are necessary conditions for solar eruption. Then we reveal a particular feature: "the fragmented neutral line". This fragmented neutral line could be interpreted as the variability of the shear angle (angle between the observed and potential horizontal field) along the neutral line. It may be an additional condition for eruption. This suggests that the active region probability of producing an eruption is not only dependent on active region free energy but also on the variability of the shear angle which appears to correspond to the fragmented neutral line.

204.4 – **Global Forces in Eruptive Solar Flares: The Lorentz Force Acting on the Solar Atmosphere and the Solar Interior**

George H. Fisher[1], D. J. Bercik[1], B. T. Welsch[1], H. S. Hudson[1]

[1]UC, Berkeley.

9:00 AM - 6:30 PM

We compute the change in the Lorentz force integrated over the outer solar atmosphere implied by observed changes in vector magnetograms that occur during large, eruptive solar flares. This force perturbation should be balanced by an equal and opposite force perturbation acting on the solar photosphere and solar

interior. The resulting expression for the estimated force change in the solar interior generalizes the earlier expression presented by Hudson, Fisher, and Welsch, providing horizontal as well as vertical force components, and provides a more accurate result for the vertical component of the perturbed force. We show that magnetic eruptions should result in the magnetic field at the photosphere becoming more horizontal, and hence should result in a downward (toward the solar interior) force change acting on the photosphere and solar interior, as recently argued from an analysis of magnetogram data by Wang and Liu. We suggest the existence of an observational relationship between the force change computed from changes in the vector magnetograms, the outward momentum carried by the ejecta from the flare, and the properties of the helioseismic disturbance driven by the downward force change. We use the impulse driven by the Lorentz-force change in the outer solar atmosphere to derive an upper limit to the mass of erupting plasma that can escape from the Sun. Finally, we compare the expected Lorentz-force change at the photosphere with simple estimates from flare-driven gasdynamic disturbances and from an estimate of the perturbed pressure from radiative backwarming of the photosphere in flaring conditions.

204.41 – **Direct Measurement Of The Height Of A White-light Flare**

Hugh S. Hudson[1], J. Martinez-Oliveros[1], S. Krucker[1], G. Hurford[1], W. Thompson[2], J. Schou[3], S. Couvidat[3], C. Lindsey[4]

[1]*UC, Berkeley,* [2]*NASA Goddard Space Flight Center,* [3]*Stanford University,* [4]*NorthWest Research Associates.*

9:00 AM - 6:30 PM

We have used RHESSI and HMI observations to observe hard X-ray and white-light continuum sources of the limb flare SOL2011-02-24, and find the source centroids to coincide within errors of about 0.2 arc s, with the conclusion that the emissions form at the same height in the atmosphere. This greatly strengthens the known association between non-thermal electrons and white-light continuum formation. We also use STEREO observations to find the heliographic coordinates of the flare. This determines the projected height of the photosphere directly below the flare emissions. With this information, the RHESSI metrology determines the absolute height of the sources to be remarkably low in the solar atmosphere: the two footpoints have comparable heights, which we estimate at about 290 +- 138 km above the photosphere. This location lies significantly below the visible-light limb height, estimated at 500 km by Brown & Christensen-Dalsgaard (1998), and the height of optical depth unity to Thomson scattering, estimated at a higher altitude. The results are not consistent with any current models of these processes.

204.42 – **Hinode/EIS Flare Spectra During RHESSI Hard X-ray Bursts**

Peter R. Young[1], H. Warren[2], G. Doschek[2]

[1]*George Mason University,* [2]*Naval Research Laboratory.*

9:00 AM - 6:30 PM

The standard flare model requires a beam of non-thermal electrons - generated at the coronal flare site - to hit the chromosphere and trigger heating and chromospheric evaporation. Ultraviolet spectrometers allow the heated, evaporating plasma to be observed and its properties measured. Observations of a M3 flare observed in 2011 September with Hinode/EIS, RHESSI and SDO/AIA will be presented, revealing the physical conditions in the flare ribbons at the time of the hard X-ray bursts. At the hottest temperatures (20 MK) upflowing plasma with speeds up to 500 km/s are found co-spatial with stationary plasma, while at cooler temperatures (0.5-2 MK) small downflows and large non-thermal broadening are found. These observations will be compared with predictions from multi-strand hydrodynamic simulations that take the RHESSI-derived electron beam spectrum as input.

204.43 – **Radio Spectroscopic Imaging of Electron Beams in the Solar Corona**

Timothy S. Bastian[1], B. Chen[2]

[1]*National Radio Astronomy Observatory,* [2]*University of Virginia.*

9:00 AM - 6:30 PM

The recently upgraded Jansky Very Large Array was used to observe the radio emission from a C class solar flare. Observations were performed from 1-2 GHz with a spectral resolution of 1 MHz and time resolution of 100 ms. A number of fast-drift, type-III-like radio bursts was observed, the result of nonthermal electron beams propagating from the flare site, guided by the coronal magnetic field. Using these dynamic, imaging, spectroscopic observations, the electron beam trajectories are deduced.Implications are briefly discussed.

204.45 – **Zoology of Solar Eruptions**

Jie Zhang[1], K. Liu[1]

[1]*George Mason Univ..*

9:00 AM - 6:30 PM

There is a wide diversity of solar eruptive events, mainly manifested as flares, CMEs, filament eruptions , and various combinations of these phenomena and many secondary effects. All these events are transient in nature, that is, gaining their energy in only minutes to tens of minutes and then returning to a quiet state. The questions are (1) what triggers and (2) what drives the energy release in each of the these phenomena, and (3) whether there is a unified theory to explain all these phenomena and their combinations. In this work, we investigate dozens of M and X-class flares observed by SDO, SOHO and STEREO, and classify these flares based on (1) their association with EUV late phase (single arcade versus double arcades) , (2) their association with CMEs (eruptive flares versus confined flares), and (3) their duration in soft X-ray fluxes (impulsive flares versus long-duration flares). These three criteria give rise of eight (2 X 2 X 2) different classes of flares. Thanks to the high-cadence-high-resolution AIA observations, we are able to study the detailed morphological and thermal evolution of these flares. "Zoological" analysis of these different eruptive phenomena will be presented. We will discuss the underlying mechanisms of these events, centered on the ideas of magnetic reconnection and magnetic flux ropes.

204.46 – **Insights Into Categorization Of Solar Flares Using Principal Component Analysis**

K. S. Balasubramaniam[1], D. C. Norquist[1]

[1]*USAF/AFRL.*

9:00 AM - 6:30 PM

Using time sequences of solar chromospheric images acquired using the USAF/NSO Improved Solar Observing Network (ISOON) prototype telescope, we have applied principal component analysis (PCA) to time-series of both erupting and non-erupting active regions. Our primary purpose is to develop an advanced data driven model for solar flare prediction using machine learning algorithms, with principal components as the input. Using the principal components we show a clear separation in the Eigen vectors. Eigen vectors fall into three major flaring categories: weak flares (GOES peak intensity < C4.0; intermediary flares (GOES peak intensity between C4.0 and C8.0) and, strong flares (GOES peak intensity > C8.0). In this paper, we will provide insights into implications for the underlying physical mechanisms that describe these three distinct categories. This work funded by the U. S. Air Force Office of Scientific Research (AFOSR).

204.47 – **Modeling the Solar Atmospheric Response to Flare-Accelerated Ion Beams**

Joel C. Allred[1], G. D. Holman[1]

[1]*NASA/Goddard Space Flight Center.*

9:00 AM - 6:30 PM

In the standard model of the impulsive phase of flares, particles accelerated to high energy at the flare reconnection site are the main source of heating in the lower atmosphere. These particles travel down magnetic flux tubes transferring their energy to the ambient plasma along the way through Coulomb collisions. It is likely that electrons as well as ions are accelerated by flare reconnection, and much work has been done understanding the response of the solar atmosphere to electron beam heating. However, since the presence of ions is much more difficult to directly detect than electrons, their role in flare heating is less understood. To better understand this, we have performed simulations of the solar atmospheric response to ion beam heating. Our models solve the equations of non-LTE radiation hydrodynamics for the conditions of the flaring solar atmosphere with an ion beam energy source term. Radiative transfer is solved in detail for many important optically thick hydrogen and helium transitions and numerous optically thin EUV lines. Thus, these models are ideally suited to study the emission that is produced during flares. We will pay special attention to understanding how key EUV lines respond to ion beam heating. We will compare these results to simulations performed with electron beam heating.

204.48 – **Low-Energy Neutron Production in Solar Flares and the Importance of their Detection in the Inner Heliosphere**

Ronald Murphy[1], B. Kozlovsky[2], G. Share[3]

[1]*NRL,* [2]*Tel Aviv University, Israel,* [3]*University of Maryland.*

9:00 AM - 6:30 PM

Neutron detectors on spacecraft in the inner-heliosphere can observe the low-energy (<30 MeV) neutrons produced in solar flares that are not easily observable at Earth; such neutrons are lost to decay during transit. We discuss calculations of low-energy neutron production using a computer code incorporating up-dated neutron-production cross sections of the accelerated proton and alpha-particle reactions with heavier elements at low ion energies (<10 MeV/nucleon) most important at these neutron energies. We calculate escaping-neutron spectra and neutron-capture gamma-ray line yields from accelerated ions propagating in a magnetic loop with various kinetic-energy spectra. The results provide the basis for planning inner-heliospheric missions containing a low-energy neutron detector. Such a neutron detector is currently in operation on the MESSENGER spacecraft orbiting Mercury. We conclude that a full understanding of ion acceleration, transport, and interaction at the Sun requires observations of both neutrons and gamma rays. We find that a measurement of the 2.223 MeV neutron-capture line, even with a modest instrument at 1 AU, is as sensitive to the presence of low-energy interacting ions at the Sun as a 1-10 MeV neutron detector at 0.5 AU. However, as the distance from the Sun to the neutron detector decreases, the tremendous increase of the low-energy neutron flux will allow exploration of ion acceleration in weak flares not previously observable and may reveal ion acceleration at other sites not previously detected where low-energy neutron production could be the only high-energy signature of ion acceleration.

204.49 – **High Cadence and High Resolution Halpha Imaging Spectroscopy of a C4.1 Flare with IBIS**

Na Deng[1], A. Tritschler[2], J. Jing[1], X. Chen[1], K. Reardon[3], C. Liu[1], Y. Xu[1], H. Wang[1]

[1]*New Jersey Institute of Technology,* [2]*National Solar Observatory,* [3]*INAF - Osservatorio Astrofisico di Arcetri, Italy.*

9:00 AM - 6:30 PM

We present a rare high cadence and high spatial resolution spectroscopic observation of a C4.1 Flare taken with the Interferometric Bidimensional Spectrometer (IBIS) in conjunction with the adaptive optics system at the 76cm Dunn Solar Telescope on 2011 October 22 in NOAA AR11324. The IBIS with a round FOV of 90"X90" and 0.1"/pix detector image scale scanned the Halpha line

from 6561.1 to 6563.8 A with 0.1 A stepsize for 28 steps. Each scan takes about 4.8s. The flare occurred in a mixed polarity region with two parasite configurations. The flare shows multiple bright ribbons in the chromosphere spreading over a region of 120"X60". IBIS observed a remote ribbon of the flare and fully covered its temporal evolution. The Halpha emission integrated over this ribbon area exhibits several bursts over four minutes during the flare impulsive phase that are temporally correlated with the subpeaks of RHESSI hard X-ray (HXR) light curves. During the strongest burst of the Halpha emission, we observe a central reversal patten in the Halpha line core, which is believed to be a signature of nonthermal process caused by direct electron precipitation. The line core shows blueward shift that increases with the Halpha emission, which might be related to chromospheric evaporation. The line width also increases with the emission. The Halpha emission is stronger in the red wing than in the blue wing during the strong bursts. Substructures within the ribbon are also identified. A bright core feature that is 30% brighter than the entire ribbon moves at an apparent velocity of about 30 km/s within the ribbon during the strongest burst of Halpha emission co-temporal with a strong subpeak of HXR. The bright core disappeared in the decay phase of the flare. We suggest that this running bright core feature tracks the site of electron precipitation.

204.5 – **Early Cruise Observations From The RAD Instrument On The Mars Science Laboratory**

Donald M. Hassler[1], C. Zeitlin[1], R. Wimmer-Schweingruber[2], S. Boettcher[2], C. Martin[2], D. Brinza[3], S. Rafkin[1], A. Posner[4], F. Cucinotta[5]

[1]Southwest Research Institute, [2]Christian Albrechts University, Germany, [3]Jet Propulsion Laboratory, [4]NASA HQ, [5]Johnson Space Center.

9:00 AM - 6:30 PM

The Radiation Assessment Detector (RAD) is a compact, lightweight energetic particle analyzer that was launched November 26, 2011 on the Mars Science Laboratory. RAD detects and analyzes energetic particle species (p, n, He, 2<Z<26) relevant for dosimetry both on the Martian surface and during cruise on its way to Mars. RAD was turned on December 6, 2011 and is working well. We will present selected early results obtained by RAD during cruise, including observations from the Solar Particle Events seen in late January, 2012.

204.51 – **Integrated Idl Tool For 3d Modeling And Imaging Data Analysis**

Gelu M. Nita[1], G. D. Fleishman[1], D. E. Gary[1], A. A. Kuznetsov[2], E. P. Kontar[3]

[1]New Jersey Institute of Technology, [2]Armagh Observatory, United Kingdom, [3]University of Glasgow, United Kingdom.

9:00 AM - 6:30 PM

Addressing many key problems in solar physics requires detailed analysis of non-simultaneous imaging data obtained in various wavelength domains with different spatial resolution and their comparison with each other supplied by advanced 3D physical models. To facilitate achieving this goal, we have undertaken a major enhancement and improvements of IDL-based simulation tools developed earlier for modeling microwave and X-ray emission. The greatly enhanced object-based architecture provides interactive graphic user interface that allows the user i) to import photospheric magnetic field maps and perform magnetic field extrapolations to almost instantly generate 3D magnetic field models, ii) to investigate the magnetic topology of these models by interactively creating magnetic field lines and associated magnetic field tubes, iii) to populate them with user-defined nonuniform thermal plasma and anisotropic nonuniform nonthermal electron distributions; and iv) to calculate the spatial and spectral properties of radio and X-ray emission. The application integrates DLL and Shared Libraries containing fast gyrosynchrotron emission codes developed in FORTRAN and C++, soft and hard X-ray codes developed in IDL, and a potential field extrapolation DLL produced based on original FORTRAN code developed by V. Abramenko and V. Yurchishin. The interactive interface allows users to add any user-defined IDL or external callable radiation code, as well as user-defined magnetic field extrapolation routines. To illustrate the tool capabilities, we present a step-by-step live computation of microwave and X-ray images from realistic magnetic structures obtained from a magnetic field extrapolation preceding a real event, and compare them with the actual imaging data produced by NORH and RHESSI instruments.

This work was supported in part by NSF grants AGS-0961867, AST-0908344, AGS-0969761, and NASA grants NNX10AF27G and NNX11AB49G to New Jersey Institute of Technology, by a UK STFC rolling grant, the Leverhulme Trust, UK, and by the European Commission through the Radiosun and HESPE Networks.

204.52 – **Time-resolved NUV And Optical Spectra Of A Stellar Megaflare On YZ CMi With SALT/RSS**

Benjamin Brown[1], A. F. Kowalski[2], M. Mathioudakis[3], E. J. Hooper[1], S. L. Hawley[2], R. A. Osten[4], J. P. Wisniewski[2]

[1]Univ. of Wisconsin - Madison, [2]University of Washington, [3]Queen's University Belfast, United Kingdom, [4]Space Telescope Science Institute.

9:00 AM - 6:30 PM

The primary mode of radiative energy release in stellar flares is in the optical and near-ultraviolet (NUV) continuum. Active M-dwarf stares flare more frequently than the Sun, and their flares can be substantially more energetic. The dominant component in solar flare white light is thought to be Hydrogen recombination, whereas for stellar M dwarf flares, the dominant component is thought to be T~10,000 K blackbody emission. Recently we have obtained very high time-cadence spectral observations of the flaring M-dwarf YZ CMi (3200-6000A) using the Robert Stobie Spectrograph on the 11-meter South African Large Telescope (SALT/RSS), achieving ~100x better temporal resolution than has previously been possible at the atmospheric limit. We observed a megaflare of over 100x flux enhancement in the NUV emission. Here we discuss the evolution of the stellar flare spectrum during the rapid impulsive phase of the flare and the implications for stellar flare models.

204 – Solar Energetic Events & Flares

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

204 – Solar Energetic Events & Flares

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

204 – Solar Energetic Events & Flares

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

205 – Interior

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

205.01 – **Torsional Oscillations Pattern from Time-distance analysis**

Shukur Kholikov[1]

[1]National Solar Observatory.

9:00 AM - 6:30 PM

We present east-west travel time differences derived from GONG data obtained for 1995-2011 time period. Our preliminary results show similar pattern of torsional oscillations published by other techniques. High latitude disagreements and possible systematic error sources will be discussed.

205.02 – **Extracting Low-Degree Timeseries and Modes from Imaged Helioseismology**

John W. Leibacher[1]

[1]National Solar Observatory.

9:00 AM - 6:30 PM

Results from a new approach to obtaining helioseismic mode time series will be presented.

205.03 – **On The Energetics Of Seismic Excitation Mechanisms**

Juan Carlos Martinez Oliveros[1], H. Bain[1], S. Krucker[1], A. Donea[2], H. Hudson[1], R. P. Lin[1], C. Lindsey[3]

[1]University of California Berkeley, [2]School of Mathematical Sciences, Monash University, Australia, [3]CoRA-NWRA.

9:00 AM - 6:30 PM

Some solar flares emit strong acoustic transients into the solar interior during their impulsive phases (Kosovichev and Zharkova, 1998). These transients penetrate thousands of kilometers beneath the active region photosphere and refract back to the surface, where they produce a characteristic helioseismic signature tens of thousands of kilometers from their origin over the succeeding hour. Several mechanisms of seismic excitation have been proposed, ranging from hydrodynamic shocks to Lorentz force perturbations. However, regardless of the mechanism of generation, it is clear that not all flares induce an acoustic response in the interior of the Sun. A concrete hypothesis or theory about the nature of this is still a topic of ongoing investigations. For some particular flares, we present a comparative study between the energy deposited by the proposed mechanisms of seismic excitation and the acoustic energy deduced using holographic techniques.

205.04 – **Multi-Wavelength Helioseismology: Power and Phase Maps in an Active Region**

Frank Hill[1], R. Howe[2], K. Jain[1], S. Tripathy[1], R. Bogart[3], C. Baldner[3], D. Haber[4]

[1]National Solar Obs., [2]University of Birmingham, United Kingdom, [3]Stanford University, [4]JILA, University of Colorado.

9:00 AM - 6:30 PM

The phase and amplitude of acoustic waves in the solar atmosphere is modified in the presence of magnetic regions. Waves at frequencies above the acoustic cutoff

show a complex pattern of changes depending on both temporal frequency and the height of formation of the quantity observed, with phase shifts as well as enhancement and suppression of power surrounding the active region. We show some examples of these effects in Doppler and intensity observations from the Helioseismic and Magnetic Imager and in the 1600 and 1700 Angstrom bands of the Atmospheric Imaging Array aboard the Solar Dynamics Observatory, probing the photosphere and lower chromosphere.

205.05 – **Meridional Circulation From Normal Mode Analysis**

Jesper Schou[1], M. F. Woodard[2], T. P. Larson[1]
[1]*Stanford Univ.,* [2]*CORA/NWRA.*
9:00 AM - 6:30 PM

We have recently been able to make significant progress in the determining the solar meridional flow from the perturbations it causes to the eigenfunctions of normal modes. In this poster we will describe some of our recent progress and show that it will likely be possible to determine the flow over a substantial part of the solar interior with a precision sufficient

to address important questions. However, we also see what appears to be significant systematic errors and will describe our efforts at understanding those.

205.06 – **Viewing Geometry, Line Height-of-Formation, and Helioseismic Measurements**

Charles Baldner[1], K. Parchevsky[1], J. Schou[1], T. Larson[1], S. Couvidat[1]
[1]*Stanford Univ..*
9:00 AM - 6:30 PM

Helioseismic mode parameters or travel times are commonly measured by observing an absorption line in the solar atmosphere and determining the line-of-sight velocity by means of the Doppler effect. Helioseismic measurements are thus susceptible to a number of systematic errors associated with the details of the line formation and wave propagation in the atmosphere. Observing at different heights in the atmosphere introduce errors through fairly simple geometric effects. In addition, mode amplitudes and eigenfunction may change with height. More complex potential sources of error include the fact that not all waves are purely evanescent, the effects of convection, the acoustic source depth and distribution, and non-adiabaticity. In this work, we report progress in characterizing the effects on helioseismic measurements by the differing height-of-formation across the disk. We consider the effects of height-of-formation on global mode parameters, ring diagram parameters, and time-distance travel time measurements.

205.07 – **An Improved 3D Radiative-MHD Model of the Convection Zone-to-Corona System**

William P. Abbett[1], D. J. Bercik[1], M. Kazachenko[1]
[1]*University of California.*
9:00 AM - 6:30 PM

We present the latest results from an improved radiative-MHD model of the convection zone-to-corona system. The numerical methods of the RADMHD model of Abbett & Fisher (2012) have been significantly updated so that the underlying finite volume scheme is (1) no longer dimensionally split along coordinate axes; (2) of much higher order accuracy using a three-dimensional 27-point stencil; and (3) capable of performing much larger scale calculations in both spherical polar coordinates and Cartesian coordinates. We will describe the improvements of the underlying scheme in detail, present a 3D dynamic convection zone-to-corona quiet Sun model using the new formalism, and compare the latest results with previous models.

205.08 – **Numerical Simulations of Solar Differential Rotation and Sub-Grid Scale Turbulence Modeling**

Gustavo Guerrero[1]
[1]*Solar Group, Stanford University.*
9:00 AM - 6:30 PM

Understanding of solar and stellar rotation has been a main challenge for

theoreticians and modelers for decades. For the solar case, helioseismology results have provided a detailed profile of surface and internal rotation which imposes strong constraints on the models. The theory of stellar rotation indicates that the rotation pattern depends on the fluxes of angular momentum. These, in turn, are defined by correlations between the small scale, turbulent, components of the velocity field. Given the enormous difference in scales present in the solar motions, resolving the turbulent scales represents a serious problem

to any global numerical model aiming to reproduce the solar differential rotation. The use of sub-grid scale (SGS) turbulence models is thus strongly required. In this work we present new results on global numerical simulation of solar rotation performed with the EULAG (Eulerian or Lagrangian frameworks) code. The numerical

method (MPDATA) corresponds to the so called implicit SGS models. It introduces a minimal amount of numerical viscosity such that the numerical stability of the

model is guaranteed. Thus the Reynolds number of the simulation is maximized for any given resolution. Our results indicate that it is possible to qualitatively reproduce a solar-like rotation pattern in the simulations even with a coarse grid

resolution. To better understand the mechanism determining the rotation pattern, we compute the turbulent fluxes of heat and angular momentum in models with different

rotation rates and resolutions. We present the results of this parametric analysis and discuss the physics of the differential rotation based on our simulations.

205.09 – **The Evolution of Large-Scale Subsurface Flow Patterns in the Sun**

Richard S. Bogart[1], C. S. Baldner[1], S. Basu[2], O. Burtseva[3], I. Gonzalez-Hernandez[3], D. A. Haber[4], F. Hill[3], R. Howe[5], K. Jain[3], R. W. Komm[3], M. C. Rabello-Soares[1], S. Tripathy[3]
[1]*Stanford Univ.,* [2]*Yale Univ.,* [3]*National Solar Observatory,* [4]*JILA/ Univ. of Colorado,* [5]*Univ of Birmingham, United Kingdom.*
9:00 AM - 6:30 PM

Ring-diagram analysis permits us to infer large-scale flow fields at the photosphere and down to depths of about 0.95 R. We present comparisons of the mean zonal and meridional velocity profiles determined from uniform analysis techniques applied to three observational data sets, those from the SDO/HMI and SOHO/MDI missions and the GONG project, over the last 18 years. We pay special attention to measurements obtained during the summer of 2010, when observations from all three observatories were available. We discuss systematic effects affecting the individual datasets in order to analyse evolution of global flows over the time scale of the solar cycle.

205.1 – **A Search for Pre-Emergence Helioseismic Signatures of Active Regions**

Graham Barnes[1], A. Birch[1], K. Leka[1], D. Braun[1], T. Dunn[1], B. Javornik[1], I. Gonzalez Hernandez[2]
[1]*NWRA,* [2]*NSO.*
9:00 AM - 6:30 PM

Helioseismology can be an important tool for understanding the formation of active regions. As a first step towards this goal, we have carried out a search for statistically significant helioseismic precursors of active region emergence. We used an automatic method to determine the time of emergence based on the NOAA/NGDC active region catalog and MDI/SOHO 96 minute magnetograms. Using GONG data, we applied helioseismic holography to 107 pre-emergence active regions and a control sample of 107 regions where no active region was present. We found some significant and surprising differences between our samples in both quantities determined from helioseismology and from surface magnetic fields. However, we do not see a clear signature of emergence when considering individual active regions. The results of this investigation may shed some light on the mechanism responsible for flux emergence, and certainly illustrate the care which must be taken in conducting such an investigation.

This work was supported by NASA contract NNH07CD25C.

205.11 – **A RHESSI and SDO Campaign Measuring Latitude-dependent Limb Profiles and Oblateness of the Optical Solar Disk II**

Martin Fivian[1], H. S. Hudson[1], R. P. Lin[1], R. I. Bush[2], M. Emilio[3], J. R. Kuhn[4], I. F. Scholl[4]
[1]*Space Sciences Lab/ UC Berkeley,* [2]*Stanford University,* [3]*Universidade Estadual de Ponta Grossa, Brazil,* [4]*Institute for Astronomy, University of Hawaii.*
9:00 AM - 6:30 PM

The SDO spacecraft conducts special roll maneuvers every 6 months. These SDO maneuvers enable its HMI instrument to obtain precise observations of the global structure of the limb. During the SDO roll on 2011 April 6 05:50-12:30 UT, we also successfully obtained RHESSI optical observations at very high cadence, 128 samples per sec for each of the three linear CCDs. A second coordinated observation with optimized parameter settings for RHESSI is planned for the time of the SDO roll maneuver in April 2012. The data from the two instruments (RHESSI/SAS and SDO/HMI), give different means for the investigation of the variation of the solar limb properties as a function of position angle (latitude). At the normal RHESSI cadence very long integrations (of order 3 months) are needed to obtain precise limb measurements, but in this case we are able to report results within the exact time frame of the SDO roll maneuver. The special RHESSI data rate was about 10,000 times larger than the standard rate and will achieve high precision in a relatively short time. We will compare these results with our earlier RHESSI observations (Fivian et al., 2008) and those obtained by Kuhn et al. (1998) and Emilio et al. (2007) with the earlier MDI roll maneuvers, and as well as with the most recent analysis of HMI data.

205.12 – **Data From The HMI Ring-Diagram Pipelines**

Richard S. Bogart[1], C. S. Baldner[1], S. Basu[2], I. Gonzalez-Hernandez[3], D. A. Haber[4], F. Hill[3], R. Howe[5], K. Jain[3], R. W. Komm[3], M. C. Rabello-Soares[1], S. Tripathy[3]
[1]*Stanford Univ.,* [2]*Yale Univ.,* [3]*National Solar Observatory,* [4]*JILA/ Univ. of Colorado,* [5]*Univ of Birmingham, United Kingdom.*
9:00 AM - 6:30 PM

The HMI data pipeline for measurement of sub-surface flows with ring-diagram analysis has been running for nearly two years, and virtually all HMI Doppler data have been analyzed. Nearly 5 million local-area power spectra have been produced and fitted for regions of various sizes, and inversions for the depth structure of flows have been performed for over 150,000 of the larger regions. The pipeline for determination of the sub-surface thermal structure is still under active development, with test results for a number of strong active regions currently available for analysis. We describe the ring-diagram pipelines, report on their performance, describe the data products available, and discuss outstanding problems and issues for further development.

205.13 – **Mode Identification In Pulsating Subdwarf B Stars Observed With Kepler Spacecraft**

Andrzej Baran[1], M. Reed[1]

[1]*Missouri State University.*

9:00 AM - 6:30 PM

We present identification of pulsation modes detected in pulsating subdwarf B stars. We used asymptotic relations and rotational splittings identifying most modes with l=1 and 2 degrees. The remaining modes may be of higher (l>2) degree. By decreasing a number of free parameters our results will help to build theoretical models which are necessary to study evolution of hot subdwarfs. Our analysis is performed on continuous Kepler space-data with unprecedented quality.

205.14 – **Analysis of Radon Decay Data and its Implications for Physics, Geophysics, and Solar Physics.**

Peter A. Sturrock[1], E. Fischbach[2], J. H. Jenkins[2], G. Steinitz[3]

[1]*Stanford Univ.,* [2]*Purdue Univ.,* [3]*Geological Survey of Israel, Israel.*

9:00 AM - 6:30 PM

We present an analysis of about 29,000 measurements of gamma radiation associated with the decay of radon in a sealed container at the Geological Survey of Israel (GSI) Laboratory in Jerusalem between January 28 2007 and May 10 2010. These measurements exhibit strong variations in time of year and time of day, which may be due in part to environmental influences. However, time-series analysis also reveals a number of periodicities, notably at 11.2 year-1 and 12.5 year-1, which we have found in other nuclear-decay data --including data acquired at the Brookhaven National Laboratory and the Physiklisch-Technische Bundesanstalt-- which we attribute to a solar influence. A distinct property of the GSI results is that the annual oscillation is much stronger in daytime data than in nighttime data, but the opposite is true for all other oscillations. We speculate on possible interpretations of this curious result. Solar neutrinos remain our prime suspect as the agent responsible for beta-decay anomalies. These results have implications for physics (that nuclear decay rates are not constant and may be stimulated); for geophysics (that the variability of radon measurements cannot be ascribed entirely to atmospheric and solid-earth processes); and for solar physics (that the Sun contains an inner tachocline, separating a slowly rotating core from the radiative zone, which has properties similar to those of the outer tachocline separating the radiative zone from the convection zone). This work was supported by DOE grant DE-AC-02-76ER071428.

205 – Interior

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

205 – Interior

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

205 – Interior

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

206 – Solar Magnetism & the Activity Cycle

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

206.01 – **A Statistical Test of Uniformity in Solar Cycle Indices**

David H. Hathaway[1]

[1]*NASA/MSFC.*

9:00 AM - 6:30 PM

Several indices are used to characterize the solar activity cycle. Key among these are: the International Sunspot Number, the Group Sunspot Number, Sunspot Area, and 10.7 cm Radio Flux. A valuable aspect of these indices is the length of the record - many decades and many (different) 11-year cycles. However, this valuable length-of-record attribute has an inherent problem in that it requires many different observers and observing systems. This can lead to non-uniformity in the datasets and subsequent erroneous conclusions about solar cycle behavior. The sunspot numbers are obtained by counting sunspot groups and individual sunspots on a daily basis. This suggests that the day-to-day and month-to-month variations in these numbers should follow Poisson Statistics and be proportional to the square-root of the sunspot numbers themselves. Examining the historical records of these indices indicates that this is indeed the case - even with Sunspot Area and 10.7 cm Radio Flux. The ratios of the RMS variations to the square-root of the indices themselves are relatively constant with little variation over the phase of each solar cycle or from small to large solar cycles. There are, however, important step-like changes in these ratios associated with changes in observer and/or observer system. Here we show how these variations can be used to construct more uniform datasets.

206.02 – **A Standard Law for the Equatorward Drift of the Sunspot Zones**

David H. Hathaway[1]

[1]*NASA/MSFC.*

9:00 AM - 6:30 PM

The latitudinal location of the sunspot zones in each hemisphere is determined by calculating the centroid position of sunspot areas for each solar rotation from May 1874 to June 2012. When these centroid positions are plotted and analyzed as functions of time from each sunspot cycle maximum there appears to be systematic differences in the positions and equatorward drift rates as a function of sunspot cycle amplitude. If, instead, these centroid positions are plotted and analyzed as functions of time from each sunspot cycle minimum then most of the differences in the positions and equatorward drift rates disappear. The differences that remain disappear entirely if curve fitting is used to determine the starting times (which vary by as much as 8 months from the times of minima). The sunspot zone latitudes and equatorward drift measured relative to this starting time follow a standard path for all cycles with no dependence upon cycle strength or hemispheric dominance. Although Cycle 23 was peculiar in its length and the strength of the polar fields it produced, it too shows no significant variation from this standard. This standard law, and the lack of variation with sunspot cycle characteristics, is consistent with Dynamo Wave mechanisms but not consistent with current Flux Transport Dynamo models for the equatorward drift of the sunspot zones.

206.03 – **Geomagnetic Indices and the Solar Magnetic Open Flux**

Aimee Ann Norton[1], W. M. Arden[2]

[1]*Stanford University,* [2]*James Cook University, Australia.*

9:00 AM - 6:30 PM

On 23 Jan 2012, an M8.7-class solar flare erupted from Active Region 1402, followed by an Earth-directed coronal mass ejection (CME) which left the Sun at approximately 750 km/s and triggered a geomagnetic storm a day later. We examine this event through the change in solar open magnetic flux computed using a potential field source surface (PFSS) model based on measurements of the photospheric magnetic field from the Solar Dynamics Observatory's Helioseismic and Magnetic Imager (SDO/HMI). We examine the solar magnetic open flux over a number of regions on the solar surface (total, northern and southern polar regions, equatorial region and both hemispheres) and correlate these with geomagnetic indices. This research is a small step in a larger project to investigate the long-term (i.e. years) correlation between open solar flux and geomagnetic activity. This correlation will lead to an increased understanding of the Sun-Earth magnetic interaction and should enhance our ability to predict space weather. The latter is increasingly critical as our terrestrial electrical and electronic infrastructure becomes more and more sensitive and vulnerable to large-scale solar activity.

206.04 – **Footpoint Separation and Evershed Flow of Active Regions**

Aimee Ann Norton[1], E. H. Jones[2]

[1]*Stanford University,* [2]*James Cook University, Australia.*

9:00 AM - 6:30 PM

The bipolar nature of active regions and sunspot groups within the Sun's photosphere is generally attributed to the emergence of magnetic flux tubes that originate from shear and turbulent pumping at the base of the Sun's convection zone. There is debate, however, as to exactly how well-connected active regions are to solar interior. A connection to the solar interior during the ascent of a flux tube through the convection zone is a requirement within numerical models designed to describe the observed characteristics of active regions, e.g. Joy's law tilt and latitude emergence, however, these models also predict post-emergence behavior of sunspots that is not supported observationally (Schussler and Rempel, 1995; Fan, 2009; Toth and Gerlei, 2003). It has been suggested (Rubio et al., 2008; Schussler and Rempel, 1995) that a bipolar magnetic region might lose its connection quickly upon emergence. Using data from SDO/HMI, we examine the footpoint separation and the Evershed flow of a number of active regions over time to detect the disconnection process of a sunspot from its magnetic roots.

206.05 – **The Vector Magnetic Fields of Sunspots as Observed with HMI**

Aimee Ann Norton[1], H. M. I. Vector Magnetic Field Team[1]

[1]*Stanford University.*

9:00 AM - 6:30 PM

The strongest sunspots yet produced by Cycle 24 are analyzed using an updated Milne-Eddington inversion code (VFISV, Borrero et al. 2010) with the full-disk polarimetric filtergram data observed with HMI. We compare the maximum strengths of the observed sunspots to those reported for ascending Cycle 23 spots. We note any magnetic field trends during daily and disk-crossing time periods that may be instrument-dependent. Updates to the inversion code include a regularization of the minimization function to bias the solution towards a lower eta0 in the case of double minima.

206.06 – **Multi-height Spectropolarimetry Of Sunspots With Firs And Ibis**

Sarah A. Jaeggli[1], H. Lin[2], A. Tritschler[3]

[1]*Montana State University,* [2]*Institute for Astronomy, University of Hawai'i,* [3]*National Solar Observatory.*
9:00 AM - 6:30 PM

The effects of radiative transfer prevent the characterization of the magnetic field at a single geometric height in the photosphere of a sunspot. Therefore, a full 3D characterization of the magnetic field is necessary to understand many properties of sunspots, such as the true state of hydrostatic equilibrium. Many current and proposed solar spectropolarimeters are capable of taking near-simultaneous observations at multiple wavelengths. Combining these rich datasets provides a welcome problem to the community. We present the first joint observations of the magnetically sensitive photospheric Fe I lines at 630 and 1565 nm taken with the Facility Infrared Spectropolarimeter (FIRS); and the chromospheric Ca II line at 854 nm taken with the Interferometric Bi-Dimensional Spectrometer (IBIS); both instruments operated at the Dunn Solar Telescope. These wavelengths allow us to probe the magnetic field over a broad range of heights, from the bottom of the photosphere to the chromosphere. We investigate the magnetic field topologies of several sunspots of different size and magnetic complexity.

206.07 – **Polar Reversal, Solar Maximum, and the Large-Scale Heliospheric Field in Solar Cycle 24**

Jon Todd Hoeksema[1]

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

The solar magnetic field in the north is weakening rapidly and will likely reverse in the next several months. The new polarity flux has emerged in active regions at lower latitude and is moving inexorably poleward. The early reversal suggests that we are fairly far along in the current solar cycle, though the weakness of the polar caps during the recent minimum may be a factor in the early reversal. The southern high latitude reversal is lagging behind. This could cause an unusual asymmetry in the heliospheric current sheet and in global solar wind conditions for an extended interval. The current cycle continues to behave in an unusual way compared with recent cycles. This work was supported by NASA.

206.08 – **Variation Of Sunspot Properties Between 1999 And 2011**

Wolfgang Schmidt[1], R. Rezaei[1], C. Beck[2]

[1]*Kiepenheuer-Institut, Germany,* [2]*Instituto de Astrofisica de Canarias, Spain.*
9:00 AM - 6:30 PM

We study the magnetic field and the umbral intensity of sunspots for the period 1999 to 2011. We analyze full Stokes spectra of 183 spots observed with the Tenerife Infrared Polarimeter at the German Vacuum Tower Telescope on Tenerife. We derive the magnetic field strength in the umbra from the Zeeman splitting of a near-infrared spectral line. This procedure eliminates the influence of non-magnetic stray light from the spot surroundings. The systematic decrease of umbral magnetic field strength observed during the declining phase of cycle 23 does not continue into cycle 24, instead, we observe a significant increase of magnetic field strength in spots of the new cycle. This indicates that the observed variations of the magnetic field strength are dominated by a cyclic effect rather than by a long-term trend.

206.09 – **Ambiguity Resolution of Multiple Height Magnetic Field Observations**

Graham Barnes[1], K. Leka[1], A. Crouch[1]

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

Typical inversions of polarized radiation and the Zeeman effect, used to infer the vector magnetic field in the photosphere or chromosphere, suffer from an inherent degeneracy in the direction of the transverse field. Many methods have been developed to treat this problem, but all must make some assumption or approximation which may not be valid. In some cases, this has led to conflicting physical interpretations of observed solar structures. One way to remove the need for the assumptions is to infer the magnetic field simultaneously at multiple heights. When line of sight variations in the vector field are available, one can use only the vanishing of the divergence of the magnetic field to resolve the ambiguity in the direction of the transverse field. We present examples of applying this technique to synthetic and observed data, and discuss how it can improve our understanding of solar magnetic structures.

This work was supported by NASA under contracts NNH09CE60C and NNH09CF22C.

206.1 – **Sunspot Dynamics as seen with CO 4666nm Spectroscopy**

Matthew J. Penn[1], T. Schad[2]

[1]*National Solar Obs.,* [2]*UA / National Solar Obs..*
9:00 AM - 6:30 PM

High resolution adaptive-optics corrected spectroscopy of sunspots using strong CO absorption lines at 4666nm was performed at the McMath-Pierce Solar Telescope using the NSO Array Camera. Active region NOAA 11158 was observed after the X-class flare on 17 Feb 2011. Several hours of rapid cadence scans reveal changes in umbral bright points, Evershed flows, flows along a sheer zone and penumbral fibrils as seen with the cool CO lines. Solar oscillations are studied, and the chromospheric structure associated with the regions of CO absorption are examined using 854.2nm Ca spectroscopy.

206.11 – **Use of a Time Delay Dynamo Model to Obtain Sun-Like Sunspot Cycles**

Ernest C. Amouzou[1], D. Nandy[2], A. Munoz-Jaramillo[3], P. C. H. Martens[1]

[1]*Montana State University,* [2]*Indian Institute of Science Education and Research, India,* [3]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

Using a time delay-based, simplified dynamo model, we attempted to produce results characteristic of the Sun when the parameters are set to solar values. We found that dynamo solutions exist for dynamo numbers less than or about equal to −3 (|ND| > 3,ND < 0) and that sunspot cycle periods of the same order of magnitude of the 11-year sunspot cycle can be obtained when the diffusive time scale and the total time delay are both about four years.

206.12 – **The Magnetic and Dynamic Structure Of An Active Region From The Photosphere To The Chromosphere**

Alexandra Tritschler[1]

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

We present preliminary results from high-resolution vector imaging spectropolarimetry of active regions obtained with the Interferometric Bidimensional Spectrometer (IBIS) operated at NSO's Dunn Solar Telescope (DST), Sunspot, New Mexico. In order to probe the photospheric-chromospheric height range, IBIS scanned consecutively the photospheric Fe I lines at 617.3 nm and 684.2 nm, the

upper photospheric/low chromospheric Na D line at 589.6 nm, and the chromospheric diagnostics Ca II 854.2 nm and H-alpha 656.3 nm (Stokes I only). We calculate two-dimensional maps of the net-circular polarisation and the total linear and circular polarisation and determine LOS Doppler velocities to characterise the structure of the magnetic and flow field, respectively.

206.13 – **Axisymmetric Flow Properties for Magnetic Elements of Differing Strength**

Lisa Rightmire-Upton[1], D. H. Hathaway[2]

[1]*University of Alabama Huntsville,* [2]*NASA MSFC.*
9:00 AM - 6:30 PM

Aspects of the structure and dynamics of the flows in the Sun’s surface shear layer remain uncertain and yet are critically important for understanding the observed magnetic behavior. In our previous studies of the axisymmetric transport of magnetic elements we found systematic changes in both the differential rotation and the meridional flow over the course of Solar Cycle 23. Here we examine how those flows depend upon the strength (and presumably anchoring depth) of the magnetic elements. Line of sight magnetograms obtained by the HMI instrument aboard SDO over the course of Carrington Rotation 2097 were mapped to heliographic coordinates and averaged over 12 minutes to remove the 5-min oscillations. Data masks were constructed based on the field strength of each mapped pixel to isolate magnetic elements of differing field strength. We used Local Correlation Tracking of the unmasked data (separated in time by 1- to 8-hours) to determine the longitudinal and latitudinal motions of the magnetic elements. We then calculated average flow velocities as functions of latitude and longitude from the central meridian for ~600 image pairs over the 27-day rotation. Variations with longitude indicate and characterize systematic errors in the flow measurements associated with changes in the signal from disk center to limb. Removing these systematic errors reveals changes in the axisymmetric flow properties that reflect changes in flow properties with depth in the surface shear layer.

206.14 – **Dynamics of the Photospheric Bright Points Observed With SST and Hinode**

Lakshmi Pradeep Chitta[1], A. van Ballegooijen[1], L. Rouppe van der Voort[2], E. DeLuca[1], R. Kariyappa[3]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Institute of Theoretical Astrophysics, University of Oslo, Norway,* [3]*Indian Institute of Astrophysics, India.*
9:00 AM - 6:30 PM

The horizontal motions of the solar magnetic bright points (BPs) observed in two wavelengths (SST Halpha and Hinode/SOT G-band) is studied in detail. With emphasis on SST results: the velocity distribution of horizontal motions is found to be a Gaussian. The auto-correlations of observed velocities is also obtained. An empirical fit to the observed auto-correlation gives us a positional uncertainty of 3 km and the error in the velocity measurements to be 0.87 km s^{-1}. Due to the non-Lorentzian, cusp-like nature of the auto-correlation, the power spectrum of the BP motions shows enhanced power at frequencies exceeding 0.02 Hz. The diffusion of magnetic field due to granular evolution at short timescales is found to satisfy a power law with a slope of 1.59.

206.15 – **Calcium II K Line as a Measure of Activity: Meshing Sac Peak and Solis Measurements**

Elana Urbach[1], J. Earley[2], S. Keil[3]

[1]*College of William and Mary,* [2]*Hidden Valley High School,* [3]*National Solar Observatory.*
9:00 AM - 6:30 PM

The Calcium II K line is an important indicator of solar and stellar activity. Disk integrated Ca K measurements have been taken at the Evans Solar Facility at Sacramento Peak Observatory since 1976. This instrument will be shut down by the end of the year, and the observations will be continued by the Solis Integrated Sunlight Spectrometer (ISS), which has been taking measurements since 2006. We attempt to regress the measurements from Sacramento Peak and ISS. In addition, we compare the Ca K measurements with disk averaged line of sight magnetic field

measurements, which will help us predict the magnetic field of other stars. We also compare the measurements with Lyman α, allowing us to use Ca K as an extreme ultraviolet (EUV) proxy. This work is carried out through the National Solar Observatory Research Experiences for Undergraduate (REU) [or Research Experiences for Teachers (RET)] site program, which is co-funded by the Department of Defense in partnership with the National Science Foundation REU/RET Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

206.16 – **Calibration of data from InfraRed Imaging Magnetograph for the New Solar Telescope**

Kwangsu Ahn[1], W. Cao[1], N. Gorceix[1], P. R. Goode[1]

[1]*Big Bear Solar Observatory.*
9:00 AM - 6:30 PM

The InfraRed Imaging Magnetograph (IRIM) takes advantage of the high spatial resolution of New Solar Telescope (NST). It adopts a rotating birefringent polymer to modulate polarization signals and two Wollaston prisms as analyzer. Dual beam setup is used to minimize the effect of image motion caused by seeing. Its field of view is 50" x 25" and the wavelengths of operation are Fe I 15648 A and He I 10830 A. Due to the off-axis shape of the NST primary and secondary mirrors, multiple calibration techniques should be combined to reconstruct the original Stokes parameters. Here, we would like to introduce current status of our calibration efforts and discuss how IRIM data can be used for scientific purposes.

206.17 – **Slitless Solar Spectroscopy**

Joseph M. Davila[1]

[1]*Goddard Space Flight Center.*
9:00 AM - 6:30 PM

Spectrographs provide a unique window into plasma parameters in the solar atmosphere. In the corona and elsewhere spectral line profiles have been used to infer microturbulence velocities, Doppler shifts have been used to measure flows, and line ratios have been used to measure temperatures. In fact spectrographs provide the most accurate measurements of plasma parameters such as density, temperature, and flow speed. However, traditionally spectrographic instruments have suffered from the inability to cover large spatial regions of the Sun quickly. To cover an active region sized spatial region, the slit must be rastered over the area of interest with an exposure taken at each pointing location. The raster process can easily take several minutes or longer to cover an active region sized area on the Sun. Because of this long cycle time, the spectra of dynamic events like flares, CME initiations, or transient brightening are obtained only rarely. And even if spectra are obtained they are either taken over an extremely small spatial region, or the spectra are not co-temporal across the raster. Either of these complicates the interpretation of the spectral raster results. Imagers are able to provide high time and spatial resolution images of the full Sun but with limited spectral resolution. The telescopes onboard the Solar Dynamics Observatory (SDO) normally take a full disk solar image every 10 seconds with roughly 1 arcsec spatial resolution. However the spectral resolution of the multilayer imagers on SDO is of order 100 times less than a typical spectrograph. We suggest an alternate reconstruction approach based on tomographic methods with regularization. Results show that the typical Doppler shift and line width error introduced by the reconstruction method is of order a few km/s at 300 A.

206.18 – **Sunrise - Prospects for the Second Science Flight**

Michael Knoelker[1]

[1]*High Altitude Observatory/NCAR.*
9:00 AM - 6:30 PM

The Sunrise balloon-borne solar observatory had a first successful science flight in June of 2009. Sunrise included of a 1m aperture Gregory telescope, a filter imager observing at 214, 300, 312, 388 and 397 nm and an imaging vector polarimeter observing in the Fe I 5250.2 line. An image stabilization system allowed for high-quality data at a resolution of around 100 km in the quiet Sun. Observations of unprecedented quality of magneto-convective processes were achieved. Extensive analysis of flight engineering data and the science data led to an impressive number of significant publications.

For the proposed second science flight improvements in the pointing and stabilization system will be employed. The addition of a magnetometer for the red-to-near-infrared wavelength range would allow for extending the high-resolution observations into the chromosphere.

The anticipated flight in June of 2013 will allow for study of large structures such as sunspots.

206.19 – **Magnetic and Thermal Effects of MHD Wave Propagation in Different Models of Sunspots**

Konstantin Parchevsky[1], A. G. Kosovichev[1]

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

Understanding of MHD wave propagation and transformation in sunspots is very important for understanding helioseismic measurements and improving helioseismic inversion procedures. Numerical simulations help to reveal details of wave interaction with the non-uniform background magnetic field and flows. Such simulations also provide artificial data for testing and calibration techniques used for analysis of data from space missions SOHO/MDI, SDO/HMI, HINODE, and GONG network.

There are three competing processes, which affect the wave speed in sunspots: (i) thermal effects, (ii) magnetic field and (iii) mass flows. Comparison of numerical simulations of the MHD wave propagation in different models of sunspot helps to disentangle these effects. We present simulation results of 3D MHD wave propagation in sunspot models with separated and combined thermal and magnetic effects. When an MHD wave enters a self-consistent magnetostatic model of the sunspot, the wave front flattens due to the reduced background sound speed near the photosphere. Later, when the wave propagates further, the wave front restores it's original shape, because waves propagate through deeper regions where contribution of the magnetic field dominates. In the model with the potential magnetic field configuration and quiet Sun background model, the wave front accelerates from the moment when the wave enters the magnetized region, forming a bulge toward the sunspot axis. Simulations also show weak fast-to-slow conversion of MHD waves near the surface where the plasma parameter beta equals one. We also present simulations in realistic sunspot model calculated by M. Rempel.

206.2 – **Pore Formation and Evolution**

Robert F. Stein[1], A. Nordlund[2]

[1]*Michigan State Univ.,* [2]*Niels Bohr Institute, Copenhagen University, Denmark.*
9:00 AM - 6:30 PM

Pores form spontaneously in magneto-convection simulations over a wide range of initial conditions. These simulations were initiated by convective inflows at the bottom advecting minimally structured, uniform, untwisted, horizontal field into the computational domain. Typically a pore forms when a magnetic loop rises through the upper boundary of the simulation domain leaving behind its two nearly vertical legs. In one case the pore formed directly in one of the legs and in another it assembled from smaller individual magnetic flux concentrations. The flux concentration that becomes a pore first forms near the surface and then extends downwards. The cooling and evacuation of the flux concentration also begin near the surface and extend downward. Eventually, the entire 20 Mm depth of the box was included. The turnover time at 20 Mm depth is about 2 days. So far the longest lived pore has existed for about half a day. One of the pores is slowly rotating. Supported by NSF grant AGS 1141921 and NASA grant NNX08AF44G.

206.21 – **Testing the Reliability of Far-side Active Region Predictions from Helioseismology using STEREO Far-side Observations**

Paulett C. Liewer[1], J. R. Hall[1], I. Gonzalez-Hernandez[2], A. Misrak[3], W. T. Thompson[4], E. M. DE Jong[1]

[1]*Jet Propulsion Laboratory, California Institute of Technology,* [2]*National Solar Observatory,* [3]*California Institute of Technology,* [4]*Adnet Systems Incorporated.*
9:00 AM - 6:30 PM

On 6 February 2011, the two Solar TERrestrial Relations Observatory (STEREO) spacecraft reached 180° separation and began imaging the entire far-side hemisphere of the Sun in extreme ultraviolet light (EUV). These new views of far-side solar activity enable us to test the reliability of helioseismology's predictions of far-side active regions using data from National Solar Observatory's Global Oscillation Network Group (GONG) and Solar Dynamics Observatory's Helioseismic and Magnetic Imager (HMI). Such predictions of far-side activity are a valuable tool for space weather forecasting. GONG produces seismic Carrington maps of strong magnetic field regions, labeling far-side regions with a probability greater than 70%. By visual comparison of these GONG maps with STEREO EUV Carrington maps, we determine whether or not solar activity, as evidenced by EUV bright regions, is observed at the locations of the predicted active regions. For GONG data from February-June 2011, we find that for 139 of 157 comparisons activity is observed in EUV at the predicted site, yielding an 89% success rate. For 18 comparisons, no activity was seen at the predicted region (11% false predictions). We also investigate the success rate for both GONG and SDO/HMI for predicting large active regions before they appear at the east limb as viewed from Earth. For large east limb active regions not predicted, STEREO's far-side observations allow us to determine whether or not strong activity was present at that location while still on the far side and thus assess whether the region might have been too weak to predict.

206.22 – **Direct Observation of the Intensity Counterpart of Moving Magnetic Features on the Photosphere and the Corresponding Vector Magnetic Fields**

Eunkyung Lim[1], V. Yurchyshyn[1], P. Goode[2]

[1]*Big Bear Solar Observatory / NJIT,* [2]*New Jersey Institute of Technology.*
9:00 AM - 6:30 PM

The formation and the temporal evolution of a bipolar moving magnetic feature (MMF) was studied with high spatio-temporal resolution. The photometric properties were observed with the New Solar Telescope at Big Bear Solar Observatory using a broadband TiO filter at 705.7nm, while the magnetic field was analyzed using the Spectropolarimetric data obtained by Hinode/SOT. From our high resolution, multi-wavelength observation, we studied 1) the detailed structure of the intensity counterpart in the photosphere of a bipolar MMF, 2) the vector magnetic field and the Doppler velocity of the MMF in time. A bipolar MMF having its positive polarity closer to the negative penumbra formed being accompanied by a bright, filamentary structure in the TiO line connecting the MMF and a dark penumbral filament. A fast downflow was detected in the positive polarity region, where the filamentary structure is seen to be brighter than its surroundings. The vector magnetic field obtained from the full Stokes inversion reveals a developing U-shaped magnetic dip between the poles of the bipolar MMF. Our observations provide the most clear intensity counterpart in the photosphere to the observed MMF, and strong evidence of the connection between the MMF and the local penumbral filament as a serpentine field.

206.23 – **Beckers Effect in a Fabry-Pérot Imaging Interferometer and Its Effects on Magnetic Field Measurements**

Brian Robinson[1], K. Balasubramaniam[2], G. Gary[3]

[1]University of Alabama in Huntsville, [2]USAF/AFRL, [3]The University of Alabama in Huntsvile/CSPAR.

9:00 AM - 6:30 PM

The Beckers effect and its impact on the optical performance of a triple-etalon Fabry-Pérot imaging spectral interferometer, such as that intended for use in the Advanced Technology Solar Telescope visible tunable filter, are analyzed in terms of its impacts on line profiles and spatial resolution. In this multi-etalon design, the interferometer is mounted in a telecentric beam. The Beckers effect refers to the pupil apodization in this configuration caused by the dependence of the spectral transmittance of Fabry-Pérot etalons on the angle of incidence of impinging rays. We find that the effect on the imaging and spectral performance can be significant even for the high F-number intermediate images required for narrowband imaging. We go on to explore the impact on Stokes line profiles at 6303Å as well as the cross-talk caused by the degraded point spread function, and analyze the resultant error in the calculated magnetic fields. We gratefully acknowledge the National Science Foundation and the National Solar Observatory for their support of this work.

206.24 – **The Three-Dimensional Reconstruction of the AR 11158 During its Emergence Phase Using SDO/HMI Observations**

Georgios Chintzoglou[1], J. Zhang[1]

[1]George Mason University, School of Physics, Astronomy and Computational Sciences.

9:00 AM - 6:30 PM

A solar active region (AR) is a three dimensional magnetic structure formed in the convection zone, whose property is fundamentally important for determining coronal structure and solar activity when emerged. However, our knowledge on the detailed 3-D structure prior to its emergence is rather poor. Previous observational work on AR emergence has been limited by instrumental capabilities - low fidelity, low-cadence magnetograms. At the same time, our theoretical knowledge relies on overly simplified assumptions based on MHD simulations or the thin flux tube approximation. Here, we are able to observationally determine and reconstruct the three-dimensional magnetic structure of AR 11158 during the emergence phase and to characterize its magnetic connectivity and topology. This task is accomplished with the aid of the time-stacking method and advanced 3-D visualization, applied on magnetograph observations from the HMI instrument of the SDO mission, taking full advantage of its unprecedented temporal resolution.

We find that the AR consists of two major dipoles. The two polarities of each dipole show interesting tree-like structure, i.e. while the bottom of the polarity appears as a single trunk-like flux tube, the top of the polarity has multiple branches, consisting of smaller and thinner flux tubes which connect to the branches of the opposite polarity. The four roots of the two dipoles align well along a straight line, while the top branches are slightly non-coplanar. The detailed 3-D topology and connectivity of AR 11158 will be presented in this meeting.

206 – Solar Magnetism & the Activity Cycle

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

206 – Solar Magnetism & the Activity Cycle

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

206 – Solar Magnetism & the Activity Cycle

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

207 – Solar Dynamics Observatory

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

207.01 – **On The Magnetic-Field Diagnostics Potential of SDO/HMI**

Bernard Fleck[1], K. Hayashi[2], R. Rezaei[3], N. Vitas[4], R. Centeno[5], M. Cheung[6], S. Couvidat[2], C. Fischer[7], O. Steiner[3], T. Straus[8], B. Viticchie[7]

[1]ESA Science Operations Department, [2]Stanford Univ., [3]KIS, Germany, [4]SRON, Netherlands, [5]HAO, [6]LMSAL, [7]ESA/RSSD, Netherlands, [8]INAF/OAC, Italy.

9:00 AM - 6:30 PM

The Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) is designed to study oscillations and the magnetic field in the solar photosphere. It observes the full solar disk in the Fe I absorption line at 6173 Å. We use the output of three high-resolution 3D, time-dependent, radiative magneto-hydrodynamics simulations (two based on the MURaM code, one on the CO^{5}BOLD code) to calculate Stokes profiles for the Fe I 6173 Å line for snapshots of a sunspot, a plage area and an enhanced network region. Stokes filtergrams are constructed for the 6 nominal HMI wavelengths by multiplying the Stokes profiles with a representative set of HMI filter response functions. The magnetic field vector B(x,y) and line-of-sight Doppler velocities V(x,y) are determined from these filtergrams using a simplified version of the HMI magnetic field processing pipeline. Finally, the reconstructed magnetic field B(x,y) and line-of-sight velocity V(x,y) are compared to the actual magnetic field B_0(x,y,z) and vertical velocity V_0(x,y,z) in the simulations.

207.02 – **Two Years of Global Analysis with HMI**

Timothy P. Larson[1], J. Schou[1]

[1]Stanford University.

9:00 AM - 6:30 PM

With HMI completing over two years of observations in May 2012, we have the opportunity to see the beginning of any trends in the global mode parameters and rotational inversions. In particular we can investigate whether the one-year periodicity seen in the f-mode frequencies measured by MDI is present in HMI. Furthermore, HMI gives us an opportunity to examine the helioseismic signals for a long span of time in observables contemporaneous with velocity, such as intensity and line depth, which MDI was unable to provide. The high resolution of the HMI instrument also gives us a chance to study in detail how the apodization of the images affects the inferred mode parameters, since our previous work has shown an as yet not understood systematic error relating to the apodization.

207.03 – **A Spatio-temporal Description of the Abrupt Changes in the Magnetic and Lorentz-force Vectors During the 2011 February 15 X2.2 Flare**

Gordon Petrie[1]

[1]NSO.

9:00 AM - 6:30 PM

Active region (AR) 11158 produced the first X-class flare of Solar Cycle 24 at 01:44~UT on February 15. The SDOHMI instrument produces 12-minute, 0.5 arcsecond/pixel vector magnetograms. Here we analyze a series of these data covering a 10-hour interval centered at the time of this flare. We describe the spatial distributions of the photospheric magnetic changes associated with this flare, including the abrupt changes in the field vector, vertical electric current and Lorentz force vector. We also trace these parameters' temporal evolution. The abrupt magnetic changes were concentrated near the neutral line and in two neighboring sunspots. Near the neutral line, the field vectors became more horizontal during the flare and the shear increased. This was due to an increase in strength of the horizontal field components near the neutral line, most significant in the horizontal component parallel to the neutral line but the perpendicular component also increased in strength. The vertical component did not show a significant, permanent overall change at the neutral line. The increase in total flux at the neutral line was accompanied by a compensating flux decrease in the surrounding volume. In both of the sunspots near the neutral line the azimuthal flux abruptly decreased during the flare but this change was permanent in only one of the spots. There was a large, abrupt, downward vertical Lorentz force change during the flare, consistent with past analyses and with recent theoretical work. The horizontal Lorentz force acted in opposite directions on each side of neutral line, with the two sunspots at each end subject to abrupt torsional forces. The shearing forces were consistent with a decrease of shear near the neutral line, whereas the field itself became more sheared as a result of the flux collapsing towards the neutral line from the surrounding volume.

207.04 – **Fix Up Your AIA Images: A Complete Empirically Determined Set of PSFs And Their Inverses for the AIA EUV Channels**

Craig DeForest[1], B. Poduval[1], J. Schmelz[2]

[1]Southwest Research Inst., [2]University of Memphis.

9:00 AM - 6:30 PM

All EUV imagers to date have had significant stray "light" in the instrument point-spread function, taking the form of very broad, low-level wings that disperse low, hard-to-measure amounts of radiance into pixels far from the core of the PSF -- but whose integrated intensity is a significant fraction of total received energy. This results in a hazy appearance to EUV images of the Sun. Thus, to obtain quantitative results from any EUV imager it is necessary to characterize the PSF via forward modeling of a distributed object rather than only (as is done on the ground) with a bright point source.

We have prepared and tested empirical PSF functions for each of the six EUV channels in the SDO/AIA instrument, and present them here. We have also prepared inverse PSFs that can be used for simple deconvolution of stray light from Level 1 AIA data: simply convolve the subject data with the inverse PSF to improve its stray light characteristics.

We present our results and some sample images, together with the imaging

improvements afforded by known-PSF deconvolution. The bottom line: AIA performs notably better than past instruments but still requires care when interpreting "diffuse" brightness in the images. We will demonstrate how deconvolution affects a particular photometric application: DEM determination of different coronal features.

207.05 – **SWAMIS Magnetic Feature Tracking for SDO**

Craig DeForest[1], D. Lamb[1], A. Davey[2], R. Timmons[3]

[1]Southwest Research Inst., [2]Smithsonian Astrophysical Observatory, [3]Lockheed-Martin.

9:00 AM - 6:30 PM

Flux emergence is central to a host of problems in solar dynamics, from the birth of new active regions and the space weather effects that result, to the maintenance of quiet sun magnetism at all phases of the solar cycle. The Southwest Automatic Magnetic Identification Suite emerging magnetic flux region detection module (SWAMIS-EF) is running on near-real-time magnetograms from the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory. This enables near-real-time automated detection and cataloging of emerging flux regions from the active region scale down to the scale of the supergranular magnetic network. We will present an overview of the emerging flux detection algorithm, show some detailed observations of emerging flux at a variety of spatial scales, and describe some of the emerging flux region summary quantities that are output to the Heliophysics Event Knowledgebase. Finally, we will describe current progress in developing Scientific SWAMIS, an adaptation and optimization of the SWAMIS tracking algorithm to run on full disk, full resolution HMI line-of-sight magnetograms.

207.06 – **Tracking Vector Magnetograms with the Helioseismic and Magnetic Imager**

Peter W. Schuck[1]

[1]Goddard Space Flight Center.

9:00 AM - 6:30 PM

We present analysis of SDO/HMI magnetograms using the Differential Affine Velocity Estimator for Vector Magnetograms with Doppler Velocities (DAVE4VMwDV) which is an extension of the local Cartesian DAVE4VM velocity estimation algorithm. The new DAVE4VMWDV inversion algorithm has several advantages specifically tailored for utilizing the SDO/HMI vector magnetograms. First, the inversion incorporates the spherical geometry of the Sun and provides direct estimates of spherical components of the plasma velocity and uncertainties. Second, the inversions may be performed in the image plane with the Jacobian computed from the gradient of the Stonyhurst coordinates at each pixel --- the data does not have to be distorted into a Mercator or other projection for analysis. Third, the profiles of plasma velocity within the local aperture are expressed as discrete Legendre polynomials of arbitrary order permitting larger apertures while preserving accuracy whereas DAVE4VM was limited to an affine (linear) velocity profile within the aperture. Fourth, the contribution of individual pixels may be weighted statistically and/or individual pixels may be eliminated from the analysis because of poor inversions and/or disambiguations. Fifth, the line-of-sight Doppler velocity may be used as a weighted constraint to improve the estimate regardless of the location of the pixel on the Sun. These advantages are unique to DAVE4VMWDV and have not been implemented in any other velocity inversion algorithms. We discuss the application of DAVE4VMWDV to simulation data and SDO/HMI vector magnetograms.

207.07 – **Helioviewer.org: Solar and Heliospheric Data Visualization**

V. Keith Hughitt[1], J. Ireland[1], D. Mueller[2]

[1]ADNET Systems/NASA, [2]ESTEC, European Space Agency, Netherlands.

9:00 AM - 6:30 PM

Over the past several years, Helioviewer.org has enabled thousands of users from across the globe to explore the inner heliosphere, providing access to over ten million images from the SOHO, SDO, and STEREO missions. Users can explore solar image archives, create movies on the fly, and interact with other solar and heliospheric services like the SDO cut-out service and the Virtual Solar Observatory (VSO). In addition to providing a powerful platform for browsing heterogeneous sets of solar data, Helioviewer.org also seeks to be as flexible and extensible as possible, providing access to much its functionality via a simple Application Programming Interface (API). The API can be used to create images and movies from data available on Helioviewer.org, or to embed a simplified version of Helioviewer.org into another website. Recently the Helioviewer.org API was used for two such applications developed by outside interests: an SDO data browser, and a Python library for solar physics data analysis (SunPy). These applications are discussed and examples of API usage are provided. Finally, Helioviewer.org is undergoing continual development with new features being added monthly. Recent changes to the web application are discussed, along with a preview of things to come.

207.08 – **SDO/AIA Observations of Sustained Coronal Condensation in Prominences as Return Flows of the Chromosphere-Corona Mass Cycle**

Wei Liu[1], T. Berger[2], B. C. Low[3]

[1]Stanford-Lockheed Institute for Space Research, [2]Lockheed Martin Solar and Astrophysics Laboratory, [3]High Altitude Observatory.

9:00 AM - 6:30 PM

It has recently been proposed that prominences are manifestations of a magneto-thermal convection process that involves ever-present dynamic descents of cool material threads and upflows of hot bubbles (Berger et al. 2011 Nature). On global scales, prominences may play an important role as the return flows of the chromosphere-corona mass cycle, in which hot mass is originally transported upward through spicules. A critical step in this cycle is the condensation of million-degree coronal plasma into T<10,000 K prominence material by radiative cooling instability. However, direct observation of coronal condensation has been difficult in the past, a situation recently changed. We present here the first example observed with SDO/AIA, in which hours of gradual cooling through multiple EUV channels (from 2 MK to 80,000 K) in large-scale loops leads to eventual condensation at magnetic dips, where we find evidence of magnetic reconnection and subsequent outflows. A moderate-size prominence of 10^14 gram is then formed. Its mass is not static but maintained by a continual supply through condensation at a high rate of 10^10 gram/s against a comparable drainage through numerous vertical threads at less than free-fall speeds. Most of the total condensation of 10^15 gram, comparable to a CME mass and an order of magnitude more than the instantaneous mass of the prominence itself, is drained in merely one day. These new observations show that a macroscopically quiescent prominence is microscopically dynamic (Liu, Berger, Low 2012 ApJL), involving the passage of a significant mass that bears important implications for the chromosphere-corona mass cycle. This interpretation is further supported by the recent theoretical development on spontaneous formation of current sheets and cool condensations (Low, Berger, Casini, & Liu, 2012 submitted to ApJ).

207.09 – **Inter-calibration Of Eis, Xrt And Aia Using Active Region And Bright Point Data**

Fana Mulu[1], A. Winebarger[1], J. Cirtain[1], S. Farid[2]

[1]NASA Marshall Space Flight Center, [2]UAHuntsville.

9:00 AM - 6:30 PM

Certain limitations in our solar instruments have created the need to use several instruments together for long term and/or large field of view studies. We will, therefore, present an inter-calibration study of the EIS, XRT and AIA instruments using active region and bright point data. We will use the DEMs calculated from EIS bright point observations to determine the expected AIA and XRT intensities. We will them compare to the observed intensities and calculate a correction factor. We will consider data taken over a year to see if there is a time dependence to the correction factor. We will then determine if the correction factors are valid for active region observations.

207.1 – **Acoustic Power Absorption in Sunspots Observed by SDO/HMI and SDO/AIA**

Sebastien Couvidat[1]

[1]Stanford Univ..

9:00 AM - 6:30 PM

Following Braun, Duvall, and LaBonte (1988) a Fourier-Hankel decomposition is applied to a dozen sunspots observed by the SDO satellite. Hill et al. (2011) showed that AIA 1600 and 1700 continuum measurements can be successfully used for helioseismic studies. Also, the acoustic-power absorption in sunspots is computed from both HMI and AIA data, and its dependence on magnetic field strength and height of formation of the lines is studied.

207.11 – **Measuring Solar Photospheric Diffusion By The Second Moment of Active Region Magnetograms**

Alexander Engell[1], D. Longcope[1]

[1]Montana State University.

9:00 AM - 6:30 PM

The process at which magnetic flux is transported on the solar photosphere is known to be dominated by diffusion, meridional flow, and differential rotation. In order to determine the diffusion constant we examine the diffusion term in the flux transport model and solve it. We study three relatively inactive active regions from HMI 12 minute magnetograms. We relate our solved diffusion equation to the second moment of our extracted magnetograms. For our active regions studied so far we find a mean diffusion constant of 256 km2s−1 with a standard deviation of 3.6 km2s−1.

207.12 – **The SDO EPO Program: Bringing Solar Data into the Community College Classroom.**

Deborah K. Scherrer[1]

[1]Stanford Univ..

9:00 AM - 6:30 PM

We will discuss a program to bring SDO solar data into the classroom by using community college students to evaluate data relating to the rotation of sunspots. Until the data cadence provided by SDO, sunspot rotation was only rarely reported. Now, with every-3-second images of from the HMI instrument on SDO, we have the opportunity to observe sunspot rotation in detail. The poster will discuss how we are using a local community college to produce a sunspot rotation laboratory.

207.13 – **An Exploration of the Emission Properties of X-ray Bright Points Seen With SDO**

Steven H. Saar[1], T. Elsden[2], K. Muglach[3]

[1]Harvard-Smithsonian, CfA, [2]University of St, Andrews, United Kingdom, [3]Goddard Space Flight Center.

9:00 AM - 6:30 PM

We present preliminary results of a study of X-ray Bright Point (XBP) EUV emission and its dependence on other properties. The XBPs were located using a new, automated XBP finder for AIA developed

as part of the Feature Finding Team for SDO Computer Vision. We analyze XBPs near disk center, comparing AIA EUV fluxes, HMI LOS

magnetic fields, and photospheric flow fields (derived from HMI data) to look for relationships between XBP emission, magnetic flux, velocity fields, and XBP local environment. We find some evidence for differences in the mean XBP temperature with environment.

Unsigned magnetic flux is correlated with XBP emission, though other parameters play a role. The majority of XBP footpoints are approaching

each other, though at a slight angle from head-on on average. We discuss the results in the context of XBP heating.

207.14 – **Global Thermodynamic MHD Modeling of the Solar Corona in the Context of SDO/AIA Observations.**

Cooper Downs[1], J. A. Linker[1], Z. Mikic[1], R. Lionello[1], P. Riley[1]

[1]*Predictive Science, Inc..*

9:00 AM - 6:30 PM

Realistic magnetohydrodynamic (MHD) models can serve as powerful testbeds for exploring our understanding of magnetic and thermodynamic processes in the solar corona. An important aspect in their development is the use of observations to characterize model results. In this context we investigate the comparison of observations from the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) to a thermodynamic MHD model of the global corona (Lionello et al. 2009), with emphasis on exploiting the unique multi-spectral information available from the AIA observing program. We discuss the implications towards modeling multi-temperature magnetic structures observed in the low corona, and focus on the sensitivity of the AIA observables with respect to the choice of coronal heating parameterizations and magnetic boundary data.

Research Supported by NASA and NSF.

207.15 – **WITHDRAWN: AIA Multithermal Analysis of Coronal Loops**

Ben Jenkins[1], J. Schmelz[1]

[1]*University of Memphis.*

9:00 AM - 6:30 PM

Simultaneous SDO Atmospheric Imaging Assembly (AIA) and Hinode EUV Imaging Spectrometer (EIS) data of coronal bright points were used to investigate the completeness of the CHIANTI atomic physics data base near the wavelengths of the AIA coronal filters. Our results not only support the conclusion that CHIANTI is incomplete near 131 A and 94 A, but more importantly, suggest that the peak temperature of the Fe VIII ionization fraction is closer to Log T = 5.8 than to Log T = 5.7. This change affects both the 131-A and 171-A AIA response functions. These empirically adjusted response functions were applied to loops that had previously been analyzed using the default response functions. As a result, the differential emission measure curves showed a more realistic shape, with no significant response around Log T = 7.0. Similarly, new loops have also been analyzed and similar results were obtained.

207.16 – **Making The Daily-updated Synoptic Map Of HMI Line-of-sight Magnetogram Cooperating With The HARP module**

Keiji Hayashi[1], Y. Liu[1], X. Sun[1], M. J. Turmon[2], HMI Team

[1]*Stanford University,* [2]*JPL/NASA.*

9:00 AM - 6:30 PM

The synoptic map of the magnetogram is widely used for the global coronal modeling, and the daily or more frequently updated maps help enhance understanding of the solar corona and interplanetary space, especially the space weather related topics. The daily-updated synoptic map is made by superimposing the latest meridional bin of the full disk data to the map. In the HMI data pipeline, the width of the bin is chosen 80 degrees in longitude around the central meridian.

A problem occurs when the boundary of the bin happens to separate the bipolar pair of the strong field: The updated part of the synoptic map may have magnetic flux unbalanced, then, the global map will have unbalanced flux and the models of the global corona, such as the PFSS, will give wrong solution. To avoid this problem, one choice is to include all (or exclude all) of the bipolar pair. The HARP, HMI Active Region Patch, will be automatically and routinely monitoring the HMI magnetogram data and recognizing the Active Region, therefore, the HARP will help minimize such unbalance of the magnetic field.

In this presentation, we will show the daily updated maps and the outputs of the coronal models, the PFSS and MHD, with the new maps,compare with the other coronal observations such as SDO/AIA images.

207.17 – **Growing Transverse Oscillations of a Multistranded Loop Observed by SDO/AIA**

Tongjiang Wang[1], L. Ofman[1], J. M. Davila[2], Y. Su[3]

[1]*Catholic Univ of America / NASA GSFC,* [2]*NASA Goddard Space Flight Center,* [3]*IGAM/Institute of Physics, University of Graz, Austria.*

9:00 AM - 6:30 PM

The flare-excited transverse loop oscillations previously observed by TRACE have been mainly interpreted as the global fast kink modes. These oscillations typically have a rapid decay, and their damping mechanism has been a major topic of theoretical studies. In this presentation, we report an unusual case of transverse loop oscillations with growing amplitudes observed by SDO/AIA for the first time. This oscillation event was triggered by a flare associated with a CME above the limb. The multiwavelength analysis reveals that the loop consists of multithermal strands and their dynamical behaviors are temperature-dependent. These strands have very similar oscillation frequencies and appear to oscillate in-phase or in a quarter-period phase delay. These features suggest the coupling between kink oscillations of neighboring strands and the interpretation by the collective kink mode as predicted by some models. The transverse loop oscillations are also associated with intensity and loop width variations. We determine the trigger of the oscillation and measure the 3-D loop geometry using STEREO/EUVI-A data. The possible mechanisms that can excite the growing kink oscillations will be discussed.

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207 – Solar Dynamics Observatory

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

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207 – Solar Dynamics Observatory

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

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207 – Solar Dynamics Observatory

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

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208 – Laboratory & Astrophysics: Atoms

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

208.01 – **Electron Impact Excitation Of Ti XIX**

Kanti M. Aggarwal[1], F. P. Keenan[1]

[1]*Queen's University Belfast, United Kingdom.*

9:00 AM - 6:30 PM

Emission lines of Ti XIX are important for the modeling and diagnostics of lasing, fusion and astrophysical plasmas, for which atomic data are required for a variety of parameters, such as energy levels, radiative rates (A- values), and excitation rates or equivalently the effective collision strengths (Y), which are obtained from the electron impact collision strengths (Ω). Experimentally, energy levels are available for Ti XIX on the NIST website, but there is paucity for accurate collisional atomic data. Therefore, here we report a complete set of results (namely energy levels, radiative rates, and effective collision strengths) for all transitions among the lowest 98 levels of Ti XIX. These levels belong to the (1s2) 2s2, 2s2p, 2p2, 2s3l, 2p3l, 2s4l, and 2p4l configurations. Finally, we also report the A- values for four types of transitions, namely electric dipole (E1), electric quadrupole (E2), magnetic dipole (M1), and magnetic quadrupole (M2), because these are also required for plasma modeling. For our calculations of wavefunctions, we have adopted the fully relativistic GRASP code, and for the calculations of Ω, the Dirac atomic R-matrix code (DARC) of PH Norrington and IP Grant. Additionally, parallel calculations have also been performed with the Flexible Atomic Code (FAC) of Gu, so that all atomic parameters can be rigorously assessed for accuracy.

208.02 – **Recent Developments with the CHIANTI Atomic Database for Astrophysical Spectroscopy**

Kenneth P. Dere[1]

[1]*George Mason Univ..*

9:00 AM - 6:30 PM

The CHIANTI atomic database for astrophysical spectroscopy maintains an assessed set of atomic data that are necessary to calculate emission from ionized plasmas that exist throughout the universe. As new atomic data becomes available, it is added to the CHIANTI database in order to improve the accuracy of data already in the database, to extend the range of spectral lines that can be reproduced or to develop new ions that are not already in the database.

Version 7 of the database was recently released (Landi et al., 2012). This included several new ions and a wide range of updated ions. A Python interface to CHIANTI, ChiantiPy, was developed to complement the existing IDL interface. A web application, based on ChiantiPy, was also developed that allows the user to make spectral calculations using the Chianti database directly from a web browser.

Version 7.1 is expected to be released in 2012 and is expected to include updated atomic data for existing ions and the develop of new ions. Ionization equilibria will be updated based on new calculations of dielectronic recombination for some isoelectronic sequences.

208.03 – **Recent Advances In The Spectral Simulation Code Cloudy**

Gary J. Ferland[1]

[1]*Univ. of Kentucky.*

9:00 AM - 6:30 PM

The spectral simulation code Cloudy is under constant development. I will outline recent improvements in the atomic, molecular, and grain physics, and discuss applications to cool core cluster filaments and star forming regions.

208.04 – **Radiative Rates for Forbidden Transitions in Doubly-Ionized Fe-Peak Elements**

Vanessa Fivet[1], P. Quinet[2], M. Bautista[1]

[1]*Western Michigan University,* [2]*Université de Mons - UMONS, Belgium.*

9:00 AM - 6:30 PM

Accurate and reliable atomic data for lowly-ionized Fe-peak species (Sc, Ti, V, Cr, Mn, Fe, Co, Ni and Cu) are of paramount importance for the analysis of the high resolution astrophysical spectra currently available. The third spectra of several iron group elements have been observed in different galactic sources like Herbig-Haro objects in the Orion Nebula [1] and stars like Eta Carinae [2]. However, forbidden transitions between low-lying metastable levels of doubly-ionized iron-peak ions have been very little investigated so far and radiative rates for those lines remain sparse or inexistent.

We are carrying out a systematic study of the electronic structure of doubly-ionized iron-peak elements. The magnetic dipole (M1) and electric quadrupole (E2) transition probabilities are computed using the pseudo-relativistic Hartree-Fock (HFR) code of Cowan [3] and the central Thomas-Fermi-Dirac potential approximation implemented in AUTOSTRUCTURE [4]. This multi-platform approach allows for consistency checks and intercomparison and has proven very successful in the study of the complex Fe-peak species where many different effects contribute [5].

References

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[5] M. Bautista et al., ApJ 718 (2010) L189

208.05 – **Eta Carinae and the Homunculus: an Astrophysical Laboratory**

Theodore R. Gull[1], H. Hartman[2], M. A. Bautista[3]

[1]*NASA/GSFC,* [2]*Lund University & Malmo University, Sweden,* [3]*Western Michigan University.*

9:00 AM - 6:30 PM

Today Eta Carinae, from the 1840s Great Eruption, is surrounded by a 20", neutral, dusty bipolar shell with intervening skirt, containing 12-40 solar masses of N-rich, C- and O-poor ejecta. The ionized Little Homunculus, ejected in the 1890s, expands within. At the core are a massive extended interacting wind structure and the bright Weigelt blobs, that change between a low-ionization (<7.8 eV) to a high-ionization state (>40 eV) driven by the 5.5-year massive binary.

Thousands of narrow emission and absorption lines originate from a variety of regions: 1) the Weigelt blobs and the extended wind structures; 2) the Strontium Filament, a unique photoioionized metal nebula dominated by TiII, VII, SrII, ScII, CaII, MnII, CrII and FeI, but no HI; 3) the ionized Little Homunculus; and 4) the Homunculus seen in nearly a thousand atomic absorption lines in high and low states, but a thousand H2 absorptions only seen in the high state. Ionized iron-peak elements co-exist with CH, OH, NH and H2. This system is an excellent laboratory for the study of many iron-peak species from neutral to doubly-ionized states. The variations of incident radiation allow us to study atomic processes and derive atomic data not available from terrestrial laboratories, making Eta Carinae an astrophysical laboratory in its true sense.

Moreover, the Homunculus, as inventoried by Herschel spectral scans, is dominated by N-bearing molecules. While C and O are depleted nearly 100-fold, due to CNO-nuclear reactions coupled with high conduction in the massive stellar cores, dust and molecules have still formed. How? Is the Homunculus dust metallic in character? Silicates and alumina? Could the formed dust also contribute to the C,O-depletions? Through multiple studies we are gaining clues on the robustness of molecular and dust formations.

208.06 – **Storage Ring Measurements of Electron Impact Ionization for Calculations of Plasma Charge State Distributions**

Michael Hahn[1], A. Becker[2], D. Bernhardt[3], M. Grieser[2], C. Krantz[2], M. Lestinsky[4], A. Müller[3], O. Novotný[1], R. Repnow[2], S. Schippers[3], K. Spruck[3], A. Wolf[2], D. W. Savin[1]

[1]*Columbia University,* [2]*Max-Planck-Institut für Kernphysik, Germany,* [3]*Justus-Liebig-Universität Giessen, Germany,* [4]*GSI Helmholtzzentrum für Schwerionenforschung, Germany.*

9:00 AM - 6:30 PM

Knowledge of the charge state distribution (CSD) of astrophysical plasmas is important for the interpretation of spectroscopic data. Reliable electron impact ionization (EII) cross sections are needed to calculate accurate CSDs for electron ionized objects such as stars, supernovae, galaxies, and clusters of galaxies. We are studying EII for astrophysically important ions using the TSR storage ring located at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. Storage ring measurements are largely free of the metastable contamination found in other experimental geometries, resulting in unambiguous EII cross section data. We have found discrepancies of 10% - 30% between the measured cross sections and those commonly used in CSD models. Because it is impractical to perform experimental measurements for every astrophysically relevant ion, theory must provide the bulk of the needed EII data. These experimental results provide an essential benchmark for such EII calculations.

208.07 – **Near-UV Atomic Line Identifications in Metal-Poor Solar-Type Stars**

Ruth Peterson[1]

[1]*Astrophysical Advances.*

9:00 AM - 6:30 PM

This poster illustrates the extent to which laboratory identifications are still needed for lines that appear in near-UV spectra, from 1900A to 3000A, of moderately metal-poor stars at and below the solar temperature. The plots compare observed high-resolution spectra of such stars to calculations from first principles. Input line parameters are based on the updated Kurucz (2011, Can. J. Phys., 89, 417) line lists, after modifying gf-values and damping constants of the identified lines to match stellar spectra over a wide variety of line strengths. Identifications and line parameters were guessed for features without identifications, designated with colons, that nonetheless appear in the spectra. Peterson (2011, ApJ, 742, 21) provides further details and recent examples for the 2000A region.

208.08 – **Radiative and Collision Atomic Parameters for N-like ions**

Swaraj S. Tayal[1]

[1]*Clark Atlanta Univ..*

9:00 AM - 6:30 PM

The improved radiative and collision atomic parameters calculations 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 74 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 and distorted-wave 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 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.

208 – Laboratory & Astrophysics: Atoms

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

208 – Laboratory & Astrophysics: Atoms

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

208 – Laboratory & Astrophysics: Atoms

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

209 – Laboratory & Astrophysics: Molecules

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

209.01 – **The ORGANIC Experiment on EXPOSE-R on the ISS: A Space Exposure Experiment**

Kathryn Bryson[1], Z. Peeters[2], F. Salama[3], B. Foing[4], P. Ehrenfreund[5], A. J. Ricco[3], E. Jessberger[6], A. Bischoff[6], M. Breitfellner[7], W. Schmidt[8], F. Robert[9]

[1]*Bay Area Environmental Research Insitute,* [2]*Carnegie Institute of Washington,* [3]*NASA Ames Research Center,* [4]*European Space Agency, ESTEC, Netherlands,*

[5]*Leiden Institute of Chemistry, Netherlands,* [6]*Westfälische Wilhelms-Universität, Germany,* [7]*European Space Astronomy Centre, Spain,* [8]*PAH Research Institute, Germany,* [9]*Laboratoire de Minéralogie et Cosmochimie du Muséum, France.*
9:00 AM - 6:30 PM

Aromatic networks are among the most abundant organic material in space. PAHs and fullerenes have been identified in meteorites and are thought to be among the carriers for numerous astronomical absorption and emission features. Thin films of selected PAHs and fullerenes have been subjected to the low Earth orbit environment as part of the ORGANIC experiment on the multi-user facility EXPOSE-R onboard the International Space Station. The ORGANIC experiment monitored the chemical evolution, survival, destruction, and chemical modification of the samples in space environment.

EXPOSE-R with its experiment inserts was mounted on the outside of the ISS from March 10, 2009 to January 21, 2011. The samples were returned to Earth and inspected in spring 2011. The 682-day period outside the ISS provided continuous exposure to the cosmic-, solar-, and trapped-particle radiation background and >2500 h of unshadowed solar illumination. All trays carry both solar-irradiation-exposed and dark samples shielded from the UV photons, enabling discrimination between the effects of exposure to solar photons and cosmic rays.

The samples were analyzed before exposure to the space environment with UV-VIS spectroscopy. Ground truth monitoring of additional sample carriers was performed through UV-VIS spectroscopy at regular intervals at NASA Ames Research Center. During the exposure on the ISS, two control sample carriers were exposed with a slight time shift in a planetary simulation chamber at the Microgravity User Support Center (MUSC) at DLR. Vacuum, UV radiation, and temperature fluctuations are simulated according to the telemetry data measured during flight. The spectroscopic measurements of these two carriers have been performed together with the returned flight samples.

We report on the scientific experiment, the details of the ground control analysis, and preliminary flight sample results. We discuss how extended space exposure experiments allow to enhance our knowledge on the evolution of organic compounds in space.

209.02 – **High Resolution Laboratory Studies for Astronomical Spectroscopy**

Harshal Gupta[1], L. R. Brown[1], B. J. Drouin[1], C. E. Miller[1], J. C. Pearson[1], K. Sung[1], S. Yu[1]

[1]*Jet Propulsion Laboratory, California Institute of Technology.*
9:00 AM - 6:30 PM

Understanding astronomical observations of molecules requires detailed spectroscopic data that can only be derived from laboratory studies. These data, including accurate transition frequencies, intensities, broadening coefficients, and collisional rates are essential for the proper characterization of the physics, chemistry, and dynamics of astronomical sources. Equally important is the comprehensive spectroscopic characterization of astronomical molecules in multiple wavelength regions. A strong effort is in place in the JPL Molecular Spectroscopy Group to provide fundamental knowledge to support ground-, aircraft-, and space-based astronomical spectroscopy. A synopsis of the high-resolution laboratory spectroscopy of astronomical molecules at JPL is presented, highlighting benchmark studies that span wavelengths from the radio to the optical. The systems under study include molecules that are ubiquitous in the interstellar medium and/or exoplanetary atmospheres (CH_4, CO_2, H_2O, and NH_3), as well as ones that have recently been shown to be important constituents of the interstellar gas (O_2, CH_3OH, H_3O^+, and HCl^+).

209.03 – **Oscillator Strengths and Predissociation Rates for $^{12}C^{16}O$ Bands between 92.9 and 93.4 nm**

Steven Robert Federman[1], M. Eidelsberg[2], J. L. Lemaire[2], G. Stark[3], A. N. Heays[3], L. Gavilan[2], J. Fillion[4], F. Rostas[2], J. R. Lyons[5], P. L. Smith[3], N. de Oliveira[6], D. Joyeux[6], M. Roudjane[6], L. Nahon[6]

[1]*Univ. of Toledo,* [2]*Observatoire de Paris, France,* [3]*Wellesley,* [4]*Univ. PVI UMPC, France,* [5]*UCLA,* [6]*Synchrotron SOLEIL, France.*
9:00 AM - 6:30 PM

We are conducting experiments on the DESIRS beam-line at the SOLEIL Synchrotron (Saint Aubin, France) to acquire the necessary data on oscillator strengths and predissociation rates for modeling CO photochemistry in astronomical environments. In particular, models of diffuse clouds, photon dominated regions associated with molecular clouds, circumstellar disks around newly-formed stars, and circumstellar envelopes surrounding evolved stars require this input. A VUV Fourier Transform Spectrometer provides a resolving power of about 350,000, allowing us to discern individual lines in electronic transitions. Here we focus on results for six overlapping bands between 92.9 and 93.4 nm seen in spectra of $^{12}C^{16}O$ and compare them with earlier determinations. Absorption from the ground electronic level, $X\ ^1\Sigma^+\ v'' = 0$, to the upper levels 4pπ(2), II $^1\Pi$, 4pσ(2), 5pπ(0), 5pσ(0), and I $^1\Pi$ was analyzed. Our results are the first to provide data on each band. The spectra also reveal a continuum feature that was synthesized, but its identification is not known at the present time.

209.04 – **A Novel Apparatus To Study Interstellar Organic Chemistry**

Aodh O Connor[1], K. A. Miller[1], J. Stützel[1], X. Urbain[2], E. F. McCormack[3], D. W. Savin[1]

[1]*Columbia University,* [2]*Université catholique de Louvain, Belgium,* [3]*Bryn Mawr College.*
9:00 AM - 6:30 PM

We have developed a new apparatus to study interstellar organic chemistry. Our focus is on ion-neutral reactions, a class of reactions which drives most of the gas-phase chemistry in the interstellar medium. The proof-of-principle measurement is $C + H_3^+ \rightarrow CH^+ + H_2$ which is believed to be a bottleneck in the gas phase chemistry leading to the formation of complex organic molecules in interstellar clouds. Previous experiments have been hampered by the difficulty in producing a sufficiently intense and well characterized beam of neutral atomic carbon. Theory provides little insight as fully quantum mechanical calculations, for four or more atom systems, are beyond current computational capabilities. Experimental reaction studies are thus required as a basis for astrochemical models and to provide benchmarks for future theoretical development. Our apparatus consists of a negative ion sputter source combined with a mass filter to generate a 30 keV C^- beam. Using an 808-nm laser (1.53 eV), we neutralize ~10% of the beam via photodetachment. The remaining C^- is electrostatically removed, yielding a well defined ground term atomic C beam. This beam is then merged with a velocity matched H_3^+ ion beam generated by a duoplasmatron ion source. As the beams are co-propagating this enables study of reactions for center-of-mass energies from tens of meV (~ 100 K) to tens of eV. Reaction channels are studied using an energy analyzer to separate the charged end products which are detected on a channel electron multiplier. Here we will report progress in the apparatus development and preliminary results. This work was supported in part by the NSF Division of Astronomical Sciences.

209.05 – **From the Laboratory to Space: Neutral and Ionized PAHs in Translucent Interstellar Clouds**

Farid Salama[1], G. Galazutdinov[2], L. Biennier[3], J. Krelowski[4]

[1]*NASA Ames Research Center,* [2]*Instituto de Astronomia, Universidad Catolica del Norte, Chile,* [3]*Institut de Physique de Rennes, UMR 6251 du CNRS, France,* [4]*Center for Astronomy, Nicolaus Copernicus University, Poland.*
9:00 AM - 6:30 PM

We describe and discuss the laboratory experiments that were designed to test the proposal of relating the origin of some of the diffuse interstellar bands (DIBs) to neutral and ionized polycyclic aromatic hydrocarbons (PAHs) present in diffuse interstellar clouds. The spectra of several cold, isolated gas-phase PAH ions and neutral molecules have been measured using the COSmIC laboratory facility at NASA-Ames and are compared with an extensive set of astronomical spectra of reddened, early type stars. The COSmIC facility combines a supersonic free jet expansion with discharge plasma and high-sensitivity cavity ringdown spectroscopy to provide experimental conditions that closely mimic the interstellar conditions. This comparison provides - for the first time - accurate upper limits for the abundances of specific PAH molecules and ions along specific lines-of-sight. Something that is not attainable from infrared observations alone. The comparison of these unique laboratory data with high resolution, high S/N ratio astronomical observations leads to major findings regarding the column densities of the individual PAH molecules and ions that are probed in this survey and leads to clear and unambiguous conclusions regarding the expected abundances for PAHs of various sizes and charge states in these environments. This quantitative survey of neutral and ionized PAHs in the optical range opens the way for unambiguous quantitative searches of PAHs and complex organics in a variety of interstellar and circumstellar environments.

Acknowledgements: F.S. acknowledges the support of the NASA's Space Mission Directorate APRA Program. The authors are deeply grateful to the ESO archive as well as to the ESO staff members for their active support.

209.06 – **Measurements of the Associative Detachment Reaction $H^- + H \rightarrow H_2 + e^-$ for Modeling Protogalaxy and First Star Formation in the Early Universe**

Daniel Wolf Savin[1], K. A. Miller[1], H. Bruhns[1], H. Kreckel[1], X. Urbain[2], J. Eliášek[3], M. Čížek[3]

[1]*Columbia Astrophysics Lab.,* [2]*Universié catholiuqe de Louvain, Belgium,* [3]*Charles University, Czech Republic.*
9:00 AM - 6:30 PM

Molecular hydrogen plays a central role in the cooling and formation of protogalaxies and first stars in the early universe. The dominant H_2 formation mechanism during this epoch is the associative detachment (AD) reaction $H^- + H \rightarrow H_2 + e^-$. Previously published values for this process differ by almost an order of magnitude. These uncertainties hinder our ability to reliably model this epoch of the universe, limiting our ability to understand the formation of protogalaxies, the characteristic masses of the first stars, and the cooling times for formation of the first stars. We have developed a novel merged-beams apparatus to measure, for the first time, the energy resolved cross section for this reaction. Beginning with an H^- beam, we use an infrared laser to convert ~ 10% of the beam into ground state H via photodetachment. This generates a self-merged, anion-neutral beams arrangement. Laboratory energies are in the keV range; but because the beams co-propagate, center-of-mass energies from the meV to keV range are achievable. We have measured the cross section for energies from 3.7 meV to 4.8 eV. Our results confirm recent non-local calculations but are not in agreement with other previously published theoretical results or with published flowing afterglow measurements. This work was supported in part by the NSF Divisions of Chemistry and Astronomical Sciences.

209.07 – **Dissociative Recombination of Astrophysically Relevant Polyatomic**

Ions

Julia Stuetzel[1], O. Novotný[1], H. Buhr[2], W. Geppert[3], M. Hamberg[3], C. Krantz[4], M. Mendes[4], A. Petrignani[4], D. Schwalm[2], A. Wolf[4], D. W. Savin[1]

[1]*Columbia University,* [2]*Weizmann Institute of Science, Israel,* [3]*Stockholm University, Sweden,* [4]*Max Planck Institute for Nuclear Physics, Germany.*

9:00 AM - 6:30 PM

Dissociative recombination (DR) of molecular ions is a key mechanism driving changes in the charge density and composition of the cold interstellar medium (ISM). In order to understand the ISM chemical network, astrochemists need total DR cross sections as well as the chemical composition and excitation states of the neutral products. Theoretical methods have not yet advanced to the point where they can reliably generate the reams of DR data required. For many polyatomic ions, experimentally investigating the DR process is the only way to gain reliable data. We have carried out DR measurements of polyatomic molecular ions utilizing the TSR storage ring at the Max-Planck-Institute for Nuclear Physics in Heidelberg, Germany. The application of a merged ion-electron beams technique, in combination with an energy- and position-sensitive imaging detector, allows for absolute rate coefficient measurements from the DR fragment count rates. Moreover, measuring the kinetic energies of the fragments of an individual breakup yields the mass identification of the neutrals and therefore the fragmentation channel for each DR event. The fragment distances on the imaging detector provide information on the reaction kinematics as well as on the initial and final excitations. Such combined information is essential for DR studies of polyatomic ions that imply multi-channel, multi-fragment breakups. We report recent DR results on D_3O^+, $DCND^+$ and D_2Cl^+. This work is supported in part by the NSF Astronomy and Astrophysics Grand Program, the NASA Astrophysics Research Analysis Program, the Max-Planck Society, and the German-Israeli Foundation for Scientific Research and Development.

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209 – Laboratory & Astrophysics: Molecules

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

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209 – Laboratory & Astrophysics: Molecules

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

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209 – Laboratory & Astrophysics: Molecules

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

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210 – Laboratory & Astrophysics: Dust & Ice

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

210.01 – **The Effects Of Methanol On The Trapping Of Volatile Ice Components**

Wendy Brown[1], D. Burke[1]

[1]*University College London, United Kingdom.*

9:00 AM - 6:30 PM

Icy mantle evaporation gives the rich chemistry observed around hot cores. Water ice is the dominant component of many astrophysical ices and this has motivated studies to identify the sublimation of volatile ice components when water-rich ices are heated. Most investigations focus on binary ices, with water as the main component. To understand thermal processing of real astrophysical ices, the current laboratory definition of these ices needs to be extended. Methanol is important in this regard, due to its close association with water. It is typically the second most abundant species and the most abundant organic molecule detected in cometary comae, interstellar ices and on a variety of bodies at the edge of our solar system. Methanol abundance varies depending on the environment, ranging from as low as 5% with respect to water in dark clouds, to approximately 30% near low and high mass proto-stars. With this in mind, we present an investigation of the adsorption and desorption of interstellar ices, showing the effect of methanol on the trapping and release of volatiles from water-rich ices. OCS and CO2 are used as probe molecules since they reside in water and methanol-rich environments.

Experiments show that OCS thermal desorption depends on ice morphology and composition. Data suggest that OCS is incorporated into amorphous water ice during heating, as a result of morphological changes in the ice, and it then explosively desorbs as the water crystallises. Similar effects are observed for OCS deposited on/within methanol ice. In contrast, OCS desorption from mixed water/methanol ices is complex. Desorption occurs at the onset of methanol desorption, in addition to co-desorption with crystalline water. Hence co-depositing impurities, e.g. methanol, with water ice significantly alters the desorption dynamics of volatiles. These results are of interest as they can be used to model star formation.

210.02 – **LASSIE - Laboratory Astrochemical Surface Science in Europe**

Wendy Brown[1]

[1]*University College London, United Kingdom.*

9:00 AM - 6:30 PM

Understanding solid state and surface chemical processes is becoming increasingly important in astrochemistry. The role of solids and surfaces in synthesising small molecules is without doubt as is their role in creating the chemical complexity from which the potential for life can spring. LASSIE (Laboratory Astrochemical Surface Science in Europe ; http://www.lassie-itn.eu) is a large training network funded by the European Commission tasked with investigating as widely as possible the role of solids and surfaces in a range of astrophysical environments. This poster will describe the membership of LASSIE, it's scientific goals and it's training role in Europe.

210.03 – **Sublimation and Irradiation of Glycolaldehyde/Water Ices**

Daren Burke[1], W. A. Brown[1], S. Viti[1], P. M. Woods[1], B. Slater[1]

[1]*University College London, United Kingdom.*

9:00 AM - 6:30 PM

There is currently great interest among astronomers and astrobiologists in the inventory of organic molecules in space, in particular in star and planet-forming regions. Observations towards the Galactic Centre have revealed a rich and complex chemistry, from simple organic molecules such as methane (CH_4) and methanol (CH_3OH) to the recent detection of ethyl formate (C_2H_5OCHO) and n-propyl cyanide (C_3H_7CN). Amongst the most important organic species detected in space is glycolaldehyde (CH_2OHCHO), an isomer of methyl formate ($HCOOCH_3$) and acetic acid (CH_3COOH). Glycolaldehyde is the simplest of the monosaccharide sugars and it reacts with propenal to form ribose, a central constituent of RNA. As a consequence, it is thought that glycolaldehyde may have a role in the origins of life in our universe.

We present a detailed investigation of the adsorption and desorption of glycolaldehyde and methyl formate using temperature programmed desorption (TPD) and reflection absorption infrared spectroscopy (RAIRS) under ultra-high vacuum. The sublimation of glycolaldehyde/water and methyl formate/water containing ices from a model carbonaceous grain surface (graphite) will be presented, along with kinetic parameters for desorption (such as the binding energy, order of desorption and desorption pre-exponential factor) derived from analysis of TPD. These experimental parameters will be incorporated into astronomical models of star-forming regions.

Additional experiments investigating the stability of glycolaldehyde/water containing ices to electron/UV irradiation will also be discussed. Electron irradiation (simulating the effect of cosmic ray ionisation, which produces electrons) and UV irradiation (over a range of wavelengths) is used to examine competing routes for non-thermal desorption, decomposition and formation. RAIRS and TPD will be used to identify any reaction products and to monitor the desorption/decomposition of glycolaldehyde as a function of irradiation time.

This work forms part of a larger project, incorporating experiment, theory and astrochemical modelling, to investigate the formation of glycolaldehyde in space.

210.04 – **Laboratory Studies of the Formation of Carbonaceous Cosmic Dust from PAH Precursors**

Farid Salama[1], C. S. Contreras[1]

[1]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

The study of the formation and destruction processes of cosmic dust is essential to understand and to quantify the budget of extraterrestrial organic molecules. Although dust with all its components plays an important role in the evolution of interstellar chemistry and in the formation of organic molecules, little is known on the formation and destruction processes of carbonaceous dust. PAHs are important chemical building blocks of interstellar dust. They are detected in interplanetary dust particles and in meteoritic samples and are an important, ubiquitous component of the interstellar medium. The formation of PAHs from smaller molecules has not been extensively studied. Therefore, it is imperative that laboratory experiments be conducted to study the dynamic processes of carbon grain formation from PAH precursors. Studies of interstellar dust analogs formed from a variety of PAH and hydrocarbon precursors as well as species that include O, N, and S, have recently been performed using the COSmIC facility in our laboratory under conditions that simulate interstellar and circumstellar environments. The species formed in the pulsed discharge nozzle (PDN) plasma source are detected and characterized with high-sensitivity cavity ringdown spectroscopy coupled to a Reflectron time-of-flight mass spectrometer (ReTOF-MS), thus providing both spectroscopic and ion mass information in-situ. We report the measurements obtained in these experiments. Studies with hydrocarbon precursors show the feasibility of specific molecules to form PAHs,

while studies with carbon ring systems (benzene and derivatives, PAHs) precursors provide information on pathways toward larger carbonaceous molecules. From these unique measurements, we derive information on the size and the structure of interstellar dust grain particles, the growth and the destruction processes of interstellar dust and the resulting budget of extraterrestrial organic molecules.

Acknowledgements: This research is supported by the NASA SMD Cosmochemistry and APRA programs. C.S.C. acknowledges the support of the NASA Postdoctoral Program.

210.05 – **Formation of Water on Dust Grains**

Gianfranco Vidali[1], D. Jing[1], J. He[1]

[1]*Syracuse Univ.*.

9:00 AM - 6:30 PM

We studied the formation of D_2O on an amorphous silicate surface using atomic deuterium and oxygen beams. Besides D_2O we detect the formation of D_2O_2; however D_2O_2 formation is greatly reduced for D/O ratios that are closer to ISM values. We also studied the diffusion of oxygen atoms and the formation of molecular oxygen and ozone [(2)].

(1) D.Jing, J.He, J.Brucato, A. De Sio, L. Tozzetti, & G.Vidali, Ap.J.L. 749, L9 (2011)

(2) D.Jing, J.He, J.Brucato, A. De Sio, L. Tozzetti, & G.Vidali, to be submitted

Financial Support from NSF Astronomy & Astrophysics Division and from MIUR PRIN-08 (Italy) is gratefully acknowledged.

210.06 – **Laboratory Spectral Studies of NH3 Ice Mixtures Relevant to Astrophysical Environments**

Douglas White[1], R. M. E. Mastrapa[2], P. A. Gerakines[3], S. A. Sandford[1]

[1]*NASA Ames Research Center,* [2]*The SETI Institute,* [3]*NASA Goddard Space Flight Center.*

9:00 AM - 6:30 PM

Small quantities of NH_3 have been detected in interstellar environments such as icy grain mantles and cometary environments via infrared (IR) absorption spectroscopy in the range λ = 0.9-25 μm (e.g., Hagen et al., 1980; Crovisier, 1997; Lacy et al., 1998). In our presentation, we will describe spectral studies of some H_2O-dominated ice mixtures containing small amounts (≤10%) of NH_3. We also present spectral data collected at the University of Alabama at Birmingham Astrophysics Laboratory of H_2O-dominated ice mixtures containing NH_3 (White 2010). Positions and profiles of absorption features of NH_3 are noted according to temperature and mixture, along with the profiles of H_2O. Mixtures with other species such as CO_2 are also investigated. These results may then be used to identify IR spectral signatures from NH_3 and other species from observational data from ground- and space-based observatories.

Crovisier, J. 1997, Earth Moon and Planets, 79, 125

Hagen, W., Allamandola, L. J., & Greenberg, J. M. 1980, A&A, 86, L3

Lacy, J. H., Faraji, H., Sandford, S. A., & Allamandola, L. J. 1998, The Astrophysical Journal Letters, 501, L105

White, D. W. 2010, PhD thesis, University of Alabama at Birmingham

210 – Laboratory & Astrophysics: Dust & Ice

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

210 – Laboratory & Astrophysics: Dust & Ice

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

210 – Laboratory & Astrophysics: Dust & Ice

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

211 – Laboratory & Astrophysics: Plasma

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

211.01 – **Thermodynamics And Convergence In Simulations Of The ICM With Anisotropic Conduction**

Mark Avara[1], C. S. Reynolds[1], T. Bogdanovic[1]

[1]*Department of Astronomy, UMD.*

9:00 AM - 6:30 PM

In the intracluster medium (ICM) of cool-core galaxy clusters, where the plasma is weakly collisional and heat conduction occurs nearly entirely along magnetic-field lines, the thermodynamics of the ICM may be significantly affected by convective instabilities driven by anisotropic heat conduction. We perform local simulations with the magnetohydrodynamic code Athena to investigate the non-linear development of the heat-flux driven buoyancy instability (HBI) and investigate the numerical convergence of such simulations as a function of magnetic field strength and numerical resolution. We identify several criteria for convergence with resolution and show that depending on the strength of magnetic field, the ICM may find itself in three different states: (1) a strong field regime in which the HBI is quenched, (2) a weak field regime in which the growth of the HBI is uninhibited, and (3) an intermediate regime when magnetic field strength is comparable to the values measured from observations of cool-core clusters. In the intermediate regime we find sustained net heat flux conducted along stable magnetic-field line filaments which may have important implications for the transport of heat into cooling cores.

211.02 – **The Madison Plasma Dynamo Experiment: a Laboratory for Astrophysics**

Benjamin Brown[1], M. D. Nornberg[1], C. B. Forest[1], E. G. Zweibel[1], J. B. Wallace[1], M. Clark[1], E. J. Spence[2], K. Rahbarnia[1], E. J. Kaplan[1], N. Z. Taylor[1]

[1]*Univ. of Wisconsin - Madison,* [2]*Princeton Plasma Physics Laboratory.*

9:00 AM - 6:30 PM

Plasma experiments in laboratory settings offer the opportunity to address fundamental aspects of the solar dynamo, magnetism in solar and stellar atmospheres, and instabilities that may play important roles in astrophysical systems. The newly constructed Madison Plasma Dynamo Experiment (MPDX) Is a platform for investigating the self-generation of magnetic fields and related processes in large, weakly magnetized, fast flowing, and hot (conducting) plasmas. Planned experiments will probe questions that are of crucial importance to heliophysics in the solar interior, atmosphere and wind. These include studying large and small scale dynamos, varying between laminar and turbulent regimes, studying stratified convection and magnetic buoyancy instabilities, and studying dissipation processes in collisionless plasmas. In addition, MPDX will allow us to study the basic physical processes underlying magnetic reconnection and flares in the solar atmosphere, the nature of CMEs, and the interactions between planetary magnetospheres and the solar wind. Results from these experiments will create the benchmarks necessary for validating heliospheric codes used to mode our Sun and forecast solar activity. Laboratory plasma experiments are likely to contribute new understanding complementary to the traditional observational and modeling approach normally used by space physicists.

211.03 – **Collaborative Comparison of High-Energy-Density Physics Codes**

Bruce Alan Fryxell[1], M. Fatenejad[2], D. Lamb[2], C. Grazianni[2], E. Myra[1], C. Fryer[3], J. Wohlbier[3]

[1]*University of Michigan,* [2]*University of Chicago,* [3]*Los Alamos National Laboratory.*

9:00 AM - 6:30 PM

Performing radiation-hydrodynamic simulations is vital to the understanding of laboratory astrophysics experiments. A number of codes have been developed for this purpose. A collaboration has begun to compare several of these codes, including CRASH (Unversity of Michigan), FLASH (University of Chicago), RAGE and CASSIO (LANL) and HYDRA (LLNL). We are in the process of testing these codes on a wide variety of problems, ranging from very simple tests to full laboratory astrophysics experiments. The algorithms and physics models differ significantly between these codes, so complete agreement is not expected, especially on the full-experiment simulations. The goal is to understand the differences between the codes and how these differences influence the results. We intend to determine which codes contain the most accurate algorithms and physics models and, where possible, to improve the other codes to produce more faithful representations of the experiments. The first set of tests are simple temperature relaxation problems in an infinite, uniform medium. The second suite of tests was designed to test the diffusion solvers (both conduction and radiation) in the codes. Following this, tests will be performed that include hydrodynamic effects. Results of these comparisons will be presented. The eventual goal is to compare the results from all of the codes on simulations of radiative shock experiments being performed by The Center for Radiative Shock Hydrodynamics at the University of Michigan and to understand any discrepancies between the results of the simulations and the experiments.

This research was supported by the DOE NNSA/ASC under the Predictive Science Academic Alliance Program by grant number DEFC52-08NA28616.

211.04 – **Radiation-Hydrodynamic Simulation of Experiments With Intense Lasers Generating Collisionless Interpenetrating Plasmas**

Michael Grosskopf[1], R. Drake[1], C. Kuranz[1], H. Park[2], N. Kugland[2], S. Pollaine[2], J. Ross[2], B. Remington[2], A. Spitkovsky[3], L. Gargate[3], G. Gregori[4], A. Bell[4], C. Murphy[4], J. Meinecke[4], B. Reville[4], Y. Sakawa[5], Y. Kuramitsu[5], H. Takabe[5], D. Froula[6], G. Fiksel[6], F. Miniati[7], M. Koenig[8], A. Ravasio[8], E. Liang[9], N. Woolsey[10]

[1]*University of Michgan,* [2]*Lawrence Livermore National Laboratory,* [3]*Princeton University,* [4]*Oxford University, United Kingdom,* [5]*Osaka University, Japan,*

[6]*Laboratory for Laser Energetics,* [7]*ETH Science and Technology University, Switzerland,* [8]*Ecole Polytechnique, France,* [9]*Rice University,* [10]*University of York, United Kingdom.*
9:00 AM - 6:30 PM

Collisionless shocks, shocks generated by plasma wave interactions in regions where the collisional mean-free-path for ions is long compared to the length scale for instabilities that generate magnetic fields, are found in many astrophysical systems such as supernova remnants and planetary bow shocks. Generating conditions to investigate collisionless shock physics is difficult to achieve in a laboratory setting; however, high-energy-density physics facilities have made this a possibility. Experiments whose goal is to investigate the production and growth of magnetic fields in collisionless shocks in laboratory-scale systems are being carried out on intense lasers, several of which are measuring the plasma properties and magnetic field strength in counter-streaming, collisionless flows generated by laser ablation. This poster reports radiation-hydrodynamic simulations using the CRASH code to model the ablative flow of plasma generated in order to assess potential designs, as well as infer properties of collected data from previous experiments.

This work is funded by the Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52- 08NA28616, by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850.

211.05 – **Theory and High-Energy-Density Laser Experiments Relevant to Accretion Processes in Cataclysmic Variables**

Christine Krauland[1], R. Drake[1], B. Loupias[2], E. Falize[2], C. Busschaert[2], A. Ravasio[3], R. Yurchak[4], A. Pelka[4], M. Koenig[4], C. C. Kuranz[1], T. Plewa[5], C. M. Huntington[1], D. N. Kaczala[1], S. Klein[1], R. Sweeney[1], B. Villette[2], R. Young[1], P. A. Keiter[1]

[1]*University of Michigan,* [2]*CEA, France,* [3]*UnEcole Polytechnique, France,* [4]*Ecole Polytechnique, France,* [5]*Florida State University.*
9:00 AM - 6:30 PM

We present results from high-energy-density (HED) laboratory experiments that explore the contribution of radiative shock waves to the evolving dynamics of the cataclysmic variable (CV) systems in which they reside. CVs can be classified under two main categories, non-magnetic and magnetic. In the process of accretion, both types involve strongly radiating shocks that provide the main source of radiation in the binary systems. This radiation can cause varying structure to develop depending on the optical properties of the material on either side of the shock. The ability of high-intensity lasers to create large energy densities in targets of millimeter-scale volume makes it feasible to create similar radiative shocks in the laboratory. We provide an overview of both CV systems and their connection to the designed and executed laboratory experiments preformed on two laser facilities. Available data and accompanying simulations will likewise be shown.

Funded by the NNSA-DS and SC-OFES Joint Prog. in High-Energy-Density Lab. Plasmas, by the Nat. Laser User Facility Prog. in NNSA-DS and by the Predictive Sci. Acad. Alliances Prog. in NNSA-ASC, under grant numbers are DE-FG52-09NA29548, DE-FG52-09NA29034, and DE-FC52-08NA28616.

211.06 – **NIF Laboratory Astrophysics Experiments Investigating The Effects Of A Radiative Shock On Hydrodynamic Instabilities**

Carolyn C. Kuranz[1], R. P. Drake[1], C. M. Huntington[1], S. R. Klein[1], M. R. Trantham[1], H. S. Park[2], B. A. Remington[2], A. R. Miles[2], K. Raman[2], J. L. Kline[3], T. Plewa[4]

[1]*University of Michigan,* [2]*Lawrence Livermore National Laboratory,* [3]*Los Alamos National Laboratory,* [4]*Florida State University.*
9:00 AM - 6:30 PM

This paper will describe ongoing laboratory astrophysics experiments at the National Ignition Facility (NIF) relevant to the complex radiation hydrodynamics that occurs in red supergiant, and core-collapse supernovae. Experiments on NIF can deliver 300 eV radiative heating that can be utilized uniquely access the regime in which radiation affects the development of hydrodynamic instabilities within an evolving object. This is relevant to the dynamics that occur during the core-collapse explosions of red supergiant stars. These stars have dense circumstellar plasma, producing a strongly radiative shock whose radiation interacts with the hydrodynamic structures produced by instabilities during the explosion. While published astrophysical simulations have not included complex, multidimensional radiation hydrodynamics, such effects are very physical and expected to affect the evolution of early stages of astrophysical objects described above. This presentation will include a summary of the two test shots that we have performed on NIF, including a 0.7 scale, gas-filled hohlraum test shot, and a description of the integrated physics shots scheduled at the facility.

This work is funded by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas under grant number DE-FG52-09NA29548 , the Lawrence Livermore National Security, LLC, under Contract No. DE-AC52-07NA27344 and Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52- 08NA28616.

211.07 – **Discrete-Ordinates and Flux-Limited-Diffusion Methods for Radiation Transport: A Comparison Study**

Eric S. Myra[1], W. D. Hawkins[2]

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

The Center for Radiative Shock Hydrodynamics (CRASH) seeks to improve the predictive capability for models of Omega laser experiments of radiative shock waves. The laser is used to shock, ionize, and accelerate a beryllium plate into a xenon-filled shock tube. These shocks, when driven above a threshold velocity of about 60 km/s, become strongly radiative and convert most of the incoming energy flux into radiation. Radiative shocks have properties that are significantly different from purely hydrodynamic shocks and, in modeling this phenomenon numerically, it is important to compute radiative effects accurately. In this presentation, we examine approaches to modeling radiation transport by comparing two methods: (i) a computationally efficient approximation (multigroup flux-limited diffusion), currently in use in the CRASH code, with (ii) a more accurate discrete-ordinates treatment that is offered by the code PDT. We present a selection of updated results from a suite of comparison tests, showing both idealized problems and those that are representative of conditions found in the CRASH experiment. This research was supported by the DOE NNSA/ASC under the Predictive Science Academic Alliance Program by grant number DEFC52-08NA28616.

211.08 – **Particle-in-cell Simulations Of Particle Energization From Low Mach Number Fast Mode Shocks**

Chuang Ren[1], E. Blackman[1], J. Park[1], R. Siller[1], J. Workman[1]

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

Collisionless perpendicular mangetosonic shocks relevant for termination shocks during solar flares are studied using two-dimensional particle-in-cell simulations with a reduced ion/electron mass ratio and a moving wall boundary condition. Compared to the reflection boundary condition, the moving wall method can control the shock speed and allows for smaller box sizes and longer simulation times in the study of shocks. In a purely perpendicular shock with the Alfven Mach number of 6.8 and plasma beta of 8. Electron and ion acceleration via shock drift acceleration (SDA) is observed. The modified two-stream instability due to the incoming and reflecting ions in the shock transition region is identified to be a possible turbulent dissipation mechanism. We determine the respective minimum energies required for electrons and ions to incur SDA. We derive a theoretical electron distribution via SDA that compares favorably to the simulation results.

This work was supported by DOE under Grant DE-FG02-06ER54879 and Cooperate Agreement No. DE-FC52-08NA28302, by NSF under Grant PHY-0903797, and by NSFC under Grant No. 11129503. The research used resources of NERSC. We also thank the OSIRIS consortium for the use of OSIRIS.

211.09 – **Developments in the Generation of Large, Laser-Driven Magnetized Collisionless Shocks**

Derek Schaeffer[1], E. T. Everson[1], D. Winske[2], C. G. Constantin[1], A. S. Bondarenko[1], K. A. Flippo[2], D. S. Montgomery[2], C. Niemann[1]

[1]*UCLA,* [2]*Los Alamos National Laboratory.*
9:00 AM - 6:30 PM

We present experiments on the Trident laser facility at Los Alamos National Laboratory and on the Phoenix laser system at the University of California-Los Angeles that demonstrate key elements in the production of laser-driven, magnetized, laboratory-scaled astrophysical collisionless shocks. These include the creation of a novel magnetic piston to couple laser energy to a background plasma and the generation of a collisionless shock precursor. We also observe evidence of decoupling between a laser-driven fast ion population and a background plasma, in contrast to the coupling of laser-ablated slow ions with background ions through the magnetic piston. 2D hybrid simulations further support these developments and show the coupling of the slow to ambient ions, the formation of a magnetic and density compression pulse consistent with a collisionless shock, and the decoupling of the fast ions.

211.1 – **A New Way to Generate Collimated Plasma Jets?**

Rachel Young[1], C. C. Kuranz[1], R. M. Sweeney[1], R. P. Drake[1]

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

We may have a new way to generate collimated, high-Mach-number plasma jets for laboratory astrophysics experiments. Analytic calculations show that irradiating the rear side of a cone-shaped foil can produce a collimated plasma jet with a Mach number of more than 2. Preliminary numeric simulations confirm this. We intend to test this method with a day of experiments at OMEGA (Laboratory for Laser Energetics, Rochester, New York) in April 2012; results may be available in time for this meeting.

If successful, this will be the first step in an experimental campaign to investigate the affects of magnetic fields on mixing plasma jets. We hope to create a swirling disk of magnetized plasma_and possibly witness the turbulent dynamo_by firing roughly half a dozen such jets towards each other. However, for such an experiment to succeed, the disk must rotate more quickly than it expands, requiring the contributing jets to have M > 2.

This work is funded by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850.

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211 – Laboratory & Astrophysics: Plasma

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

211 – Laboratory & Astrophysics: Plasma

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

211 – Laboratory & Astrophysics: Plasma

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

212 – Laboratory & Astrophysics: Planetary

Poster Session – Exhibit Hall, Dena'ina Center – 6/11/2012 9:00:00 AM to 6/14/2012 6:30:00 PM

212.01 – **Probing the effect of Gases on Activated Lunar Simulant**

F. Salama[1], C. L. Ricketts[1], **Ella Sciamma-O'Brien**[1], C. S. Contreras[1], A. L. Mattioda[1], E. L. Yates[1], L. T. Iraci[1], A. Ricca[1]

[1]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

The lunar surface is constantly 'activated' through bombardment of solar radiation and micrometeorites. This 'activation' is significant enough to affect the surface dust by creating free radicals, dangling bonds and lattice defeats. Hence, the reactive effect of the dust particles on spacecraft instrumentation and human toxicology is a concern. There is currently little information on the surface chemical activation of lunar regolith after exposure to gases brought to the Moon by human activities. Information is needed in order to understand the regolith toxicity, effect on spacecraft, determine lunar dust exposure limits and meet the needs of the technological development of appropriate physical/chemical tools for regolith passivation.

In this experimental study, we grind JSC-1af lunar simulant to simulate micrometeorite impacts and expose the simulant to vacuum ultraviolet (VUV) light to simulate solar radiation. We then flow a variety of gases (N2, CO2, CH4) over the simulant to simulate the exposure of the activated dust to gases humans would bring to the Moon. Mass spectra are taken using the Reflectron Time-Of-Flight Mass Spectrometer at NASA Ames' Cosmic Simulation facility (COSmIC), before, during and after exposure to VUV and the various gases. Infrared spectra and Scanning Electron Microscope images of the simulant are taken, before and after activation and gas exposure. Future plans include theory and replicating these experiments using real lunar dust. Here we describe our new custom built lunar dust holder, experimental procedure and latest results.

Acknowledgments: NASA LASER supports this research. E.S.O. and C.S.C. acknowledge the support of the NASA Postdoctoral Program.

212.02 – **Laboratory Simulations Of Titan's Atmospheric Chemistry With The NASA Ames Titan Haze Simulation Experiment**

Ella Sciamma-O'Brien[1], C. S. Contreras[1], C. L. Ricketts[1], F. Salama[1]

[1]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

Solar UV radiation and electron bombardment from Saturn's magnetosphere dissociate nitrogen and methane in Titan's atmosphere, leading to the production of heavier molecules and solid organic aerosols that contribute to the haze layers giving Titan its characteristic orange color. The detection of benzene and toluene, critical precursors of polycyclic aromatic hydrocarbon (PAH), in Titan's ionosphere, by the Cassini INMS suggests that PAHs might play a role in the production of Titan's aerosols. The Titan Haze Simulation (THS) experiment has been developed at NASA Ames' Cosmic Simulation facility (COSmIC) to study the chemical pathways that link the simple molecules resulting from the first steps of the N2-CH4 chemistry (C2H2, C2H4, HCN..) to benzene, and to PAHs and nitrogen-containing PAHs (PANHs) as precursors to the production of solid aerosols. In the THS experiment, Titan's atmospheric chemistry is simulated by plasma in the stream of a supersonic jet expansion. With this unique design, the gas mixture is cooled to Titan-like temperature (~150K) before inducing the chemistry by plasma discharge. Different gas mixtures containing the first products of Titan's N2-CH4 chemistry, but also much heavier molecules like PAHs or PANHs can be injected to study specific chemical reactions. The products of the chemistry are detected and studied using Cavity Ring Down Spectroscopy and Time-Of-Flight Mass Spectrometry. Thin tholin (Titan aerosol analogs) deposits are also produced in the THS experiment and can be analyzed by Gas Chromatography-Mass Spectrometry (GC-MS) and Scanning Electron Microscopy (SEM). We present the results of mass spectrometry studies using different gas mixtures, and discuss their relevance for the study of specific pathways in Titan's atmospheric chemistry.

Acknowledgements: This research is supported by NASA PATM. E.S.O., C.S.C. and C.L.R acknowledge the support of the NASA Postdoctoral Program. The authors acknowledge the collaboration of H. Imanaka, C. McKay and S. Lebonnois.

212 – Laboratory & Astrophysics: Planetary

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

This session includes the same abstracts from the previous session.

212 – Laboratory & Astrophysics: Planetary

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

This session includes the same abstracts from the previous session.

212 – Laboratory & Astrophysics: Planetary

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

This session includes the same abstracts from the previous session.

300 – SPD Harvey Prize: The Solar Cycle: From Understanding to Forecasting

Invited Session – Ballroom B, Dena'ina Center – 6/12/2012 8:30:00 AM to 6/12/2012 9:20:00 AM

300.01 – **The Solar Cycle: From Understanding to Forecasting**

Dibyendu Nandy[1]

[1]*Indian Institute of Science Education and Research, Kolkata, India.*

8:30 AM - 9:20 AM

Solar and stellar magnetic cycles are born out of a magnetohydrodynamic dynamo mechanism involving interactions between internal plasma flows and magnetic fields. The Sun offers a unique opportunity of exploring this dynamo mechanism in detail. The solar cycle is manifested as a periodic variation in the number of sunspots. This magnetic activity spawns severe space weather which can adversely affect technologies exposed to environmental conditions in space. It is also thought that slower, long-term variations in the Sun's magnetic activity influence planetary climates such as that of the Earth. Understanding the physical processes that generate the solar cycle is therefore of fundamental importance. While it is expected that this understanding should also lead to reliable predictive capabilities, unfortunately, forecasts for the amplitude of the (ongoing) solar cycle 24 have not converged. In this talk, after providing an introduction to solar dynamo theory, I will review our current state of understanding and critically discuss the underlying physics of solar cycle predictability.

301 – Bridging Laboratory and Astrophysics: Molecules

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying molecular processes which drive our cosmos.

301.01 – **Interstellar Molecules: Laboratory, Theoretical and Astronomical Studies**

David A. Neufeld[1]

[1]*Johns Hopkins University.*

10:00 AM - 10:30 AM

Our understanding of interstellar molecules rests critically upon laboratory and theoretical studies of fundamental molecular processes: the absorption and emission of radiation; bimolecular chemical reactions; photodissociation and photoionization; and collisional excitation. The importance of such studies will be discussed in relation to recent observations of molecules performed with the Herschel Space Observatory. As a specific example, some puzzling observations of

chlorine-bearing molecular ions will be considered.

301.02 – **Gas Phase Theoretical Kinetics for Astrochemistry**

Stephen J. Klippenstein[1], Y. Georgievskii[1], L. B. Harding[1]

[1]*Argonne National Laboratory.*
10:30 AM - 11:00 AM

We will survey a number of our applications of ab initio theoretical kinetics to reactions of importance to astrochemistry. Illustrative examples will be taken from our calculations for (i) interstellar chemistry, (ii) Titan's atmospheric chemistry, and (iii) the chemistry of extrasolar giant planets. For low temperature interstellar chemistry, careful consideration of the long-range expansion of the potential allows for quantitative predictions of the kinetics. Our recent calculations for the reactions of H_3^+ with $O(^3P)$ and with CO suggest an increase of the predicted destruction rate of H_3^+ by a factor of 2.5 to 3.0 for temperatures that are typical of dense clouds. Further consideration of the interplay between spin-orbit and multipole terms for open-shell atomic fragments allows us to predict the kinetics for a number of the reactions that have been listed as important reactions for interstellar chemical modeling [V. Wakelam, I. W. M. Smith, E. Herbst, J. Troe, W. Geppert, et al. Space Science Rev., 156, 13-72, 2010]. Our calculations for Titan's atmosphere demonstrate the importance of radiative emission as a stabilization process in the low-pressure environment of Titan's upper atmosphere. Theory has also helped to illuminate the role of various reactions in both Titan's atmosphere and in extrasolar planetary atmospheres. Comparisons between theory and experiment have provided a more detail understanding of the kinetics of PAH dimerization. High level predictions of thermochemical properties are remarkably accurate, and allow us to provide important data for studying P chemistry in planetary atmospheres. Finally, our study of $O(^3P) + C_3$ provides an example of a case where theory provides suggestive but not definitive results, and further experiments are clearly needed.

301.03 – **Cracking the Astrochemical Code: Molecular Spectroscopy in Support of Observational Astrophysics**

Susanna L. Widicus Weaver[1]

[1]*Emory University.*
11:00 AM - 11:30 AM

The development of the next generation of astronomical instrumentation has placed molecular astrophysics research at a crossroads. The Herschel, SOFIA, and ALMA observatories are providing spectral observations that have sensitivity limits well below those of any preceding ground-based observations. These observatories are also operating at frequencies that are ideal for probing the molecular universe. The broadband spectral acquisition capabilities of these observatories will eliminate the tedious, one-line-at-a-time approach to molecular observations that has historically hampered ground-based radioastronomical identification of molecules. The ALMA observations will advance this field even further, providing highly spatially-resolved molecular information in addition to broadband spectral acquisition. The expected amount of information from these new facilities is quite daunting because the laboratory spectral database that will enable interpretation of these observations is severely lacking. Likewise, the tools needed to analyze both the laboratory and observational spectra are also lacking. Laboratory spectral surveys across the frequency ranges covered by these instruments have not been completed for even the most abundant interstellar molecules, commonly referred to as ``interstellar weeds," let alone the majority of the ~170 interstellar molecules identified to date. This lack of laboratory spectral information will limit interpretation of the observational spectra, which will be near the line-confusion limit. Fortunately the hardware and technology advancements associated with the construction of these observatories has also spurred new developments in laboratory spectroscopic techniques. In this talk I will overview the current state-of-the art in molecular laboratory spectroscopic techniques used to study molecules of astrophysical interest, and will highlight recent successes in laboratory efforts that complement new astronomical observations. I will also discuss the remaining needs for molecular spectroscopic information to support observational astrophysics.

302 – Multiple Populations in Globular Clusters: Abundances & Stellar Models

Meeting-in-a-Meeting – Room 3, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

This session focuses on understanding the chemical differences among populations within globular clusters, including application of and constraints from stellar models, as well as open problems.

302.01 – **The Challenges of omega Centauri**

John E. Norris[1]

[1]*Mount Stromlo & Siding Spring Observatories, Australia.*
10:00 AM - 10:22 AM

It is now five decades since the demonstration that the color magnitude diagram (CMD) of omega Cen is unlike that of other globular clusters. This was followed, slowly but surely, by the appreciation that omega contains a large number (some five and counting) of discrete populations. The challenge being addressed is the determination of the spatial, chemical abundance, kinematic, and age distributions of these populations, and their inter-relationships - which will constrain our understanding of the origin and evolution of the system. The present contribution addresses the problems currently posed by our interpretation of the existing data set.

With exquisite photometry, discrete sequences are now clearly seen in the CMD well down onto the main sequence. This is accompanied by high-resolution spectroscopy (albeit not to such faint levels), permitting insight into the abundance and kinematic distributions of large samples. Ages, however, are very difficult to determine, and those available defy simple interpretation in terms of population parameters. Major problems are now evident. Consider the multiple main sequence: if this results from postulated large helium abundance differences (Y in the range 0.25 - 0.40), what is the origin of the extremely high values. Is it really helium that is varying?! Second, one needs a reconciliation of the CMD sequences in terms of the abundances (He, CNO and Fe) and ages of the relevant populations. How do three populations on the main sequence telescope to five (or more) on the post main sequence giant branches? Where do the populations evolve onto the horizontal branch and the white dwarf sequence? What drives variations in population parameters with distance from cluster center? Finally, if omega Cen is the remnant of a nucleated dwarf galaxy captured long ago by the Milky Way, where is the debris of that event among the Galaxy's field halo population?

302.02 – **Photometry of Multiple Stellar Populations in Globular Clusters**

Antonino Milone[1]

[1]*Instituto de Astrofisica de Canarias, Spain.*
10:22 AM - 10:44 AM

An increasing number of observations over the last years have shown the existence of distinct sub-populations in many (maybe all) globular clusters and shattered the paradigm of globulars hosting single, simple stellar populations. These multiple populations manifest themselves in a split of different evolutionary sequences in the cluster color-magnitude diagrams.

Using filters covering an appropriate range of wavelengths, photometry splits the main sequence into two or more branches, and in many cases this bimodality is repeated in the subgiant and red giant regions, and on the horizontal branch.

In this talk I will summarize the main results from photometric studies.

302.03 – **Agb And Sagb Stars In A Possible Scenario For The Formation Of Multiple Populations In Globular Clusters**

Paolo Ventura[1]

[1]*INAF - Observatory of Rome, Italy.*
10:44 AM - 11:06 AM

Winds from AGB and SAGB stars are believed to be the main polluters of the interstellar medium in Globular Clusters, ejecting in their surroundings gas, from which new stellar generations form. In this contribution we summarize how the current generation of AGB models can reproduce the abundance patterns observed, and stress the open

points still debated with this interpretation.

302.04 – **Massive Stars and Their Possible Impacts in Globular Clusters**

Thibaut Decressin[1]

[1]*Geneva Observatory, Switzerland.*
11:06 AM - 11:30 AM

Globular clusters exhibit peculiar chemical patterns where Fe and heavy elements abundances stay constant inside a given cluster while light elements (Li to Al) show strong star-to-star variations. This peculiar chemical pattern can be explained by self-pollution of the intracluster gas occurring in the early evolution of clusters. Here I present the possible strong impact of fast rotating massive stars on clusters evolution. First providing they rotate initially fast enough, these stars can reach the break-up velocity during the main sequence and matter will be ejected from the equator at low velocity. Rotation-induced mixing will also bring matter from the convective core to the surface. From this ejected matter loaded in H-burning material a second generation of stars will born. The chemical pattern of these second generation stars are similar to the one observed for stars in globular cluster with abundance anomalies in light elements. Then during the explosion as supernovae the massive stars will also clear the cluster of the remaining gas. One important feature of globular clusters observed today is that 50 to 80% of the low mass stars still evolving in the cluster are second generation starts whereas, with a standard IMF, these stars should be at most 10% of the cluster stars. This strong discrepancy can be solved if the proto-globular clusters were more massive (up to a factor 20-30) and mass-segregated during their formation. In this case a strong loss of first generation stars occupying the outer part of the cluster is possible through the dynamical history of the cluster.

303 – Wide-Field IR Space Telescope Science: Introduction and Survey Science

Meeting-in-a-Meeting – Summit Hall 3, Egan Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

The Astro2010 Decadal Survey gave its highest recommendation in the large-scale space mission category to WFIRST, a Wide-Field Infrared Survey Telescope with both imaging and spectroscopy capabilities. The science made possible by such a facility reaches across many disciplines from dark energy to exoplanets to deep surveys. The proposed mission will conduct

microlensing observations of stars in the galactic bulge, near-IR surveys of thousands of square degrees to magnitudes limits of AB ~25, spectroscopic measurements of a hundred million galaxies to redshift accuracy of ~0.1% and precision supernova observations into the near-IR of thousands of events. It will be a powerful tool for the astronomical community. The purpose of this workshop is to inform the community of the planned capabilities and gather input for defining the mission and its science.

303.01 – **WFIRST: Big Science with a Small Telescope**

Alan Dressler[1]

[1]*Carnegie Observatory.*

10:00 AM - 10:20 AM

The Pasadena meeting "Science with a Wide-Field Infrared Telescope in Space,", February 13-15, reviewed the remarkable scientific capabilities of WFIRST and progress towards a consensus design. I will review some of the highlights of this noteworthy meeting and describe some of the steps that might be taken to achieve a WFIRST launch in the early 2020's.

303.02 – **Cosmic Acceleration: Standard Candles and Standard Rulers**

Paul Schechter[1]

[1]*MIT.*

10:20 AM - 10:40 AM

The expansion history of the universe is measured by comparing either the apparent brightnesses of standard candles or the angular diameters of standard rulers at different redshfits. WFIRST will use both a standard candle (type Ia supernovae) and a standard ruler (the bump in the galaxy correlation function due to baryon accoustic oscillations). Moreover, WFIRST will also probe the expansion history by determining the relative distances to sources at different redshifts, achieved by comparing the "weak" gravitational lensing signal -- the amount by which the lensing distorts galaxy images. The physics behind each of these methods will be discussed, as will the extent to which that physics is as yet uncertain.

303.03 – **Extragalactic Science and Cosmology with WFIRST**

Richard S. Ellis[1]

[1]*Caltech.*

10:40 AM - 11:00 AM

The low background at near-infrared wavelengths in space offers unrivaled scientific opportunities for a wide-field facility with imaging and spectroscopic capabilities such as WFIRST. In conjunction with undertaking several complementary and definitive measures of large scale structure and its cosmic evolution, WFIRST will provide a legacy of deep multi-color imaging and precise spectroscopic redshifts over tens of thousands of square degrees. Through its proposed Guest Investigator program, WFIRS will also offer valuable additional science and synergies with other facilities. I will review the exciting extragalactic science and cosmology possible with WFIRST as well as the context of the mission in the light of expected ground-based programs during the next decade.

303.04 – **A Study of Stellar Populations in the Local Volume with WFIRST**

Jason S. Kalirai[1]

[1]*Space Telescope Science Institute.*

11:00 AM - 11:20 AM

The study of resolved stellar populations in the Local Volume represents an anchor for many relations in astrophysics. High-precision, deep imaging observations of Galactic star clusters calibrate the theory of stellar evolution, wide-field surveys of stellar halos inform hierarchical merging models, and spectroscopy of disk and bulge stars yield the history of chemical evolution processes. The most frequent observational probes of these precious systems has involved either deep pencil beam studies of specific objects (e.g., HST imaging) or utilized wide field surveys to target an ensemble of objects to shallow limits (e.g., SDSS). A common aspect of most previous investigations of nearby resolved stellar populations is that they have focussed on visible-light studies. In this talk, I will discuss a new panchromatic survey that can be uniquely enabled through the synergy of these existing studies with a new high-resolution wide-field imaging survey from space. I will highlight the implications of this survey on several astrophysical topics, including the initial mass function, hydrogen burning limit, L and T dwarf evolution, star formation law, color-magnitude relation, and stellar mass loss processes.

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304 – New Horizons for Science From the Moon: Heliophysics, Coronal Mass Ejections & Space Weather

Meeting-in-a-Meeting – Summit Hall 2, Egan Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

High energy particle acceleration occurs in diverse environments including the Sun, stars, supernovae, and AGNs. Fundamental problems include understanding the mechanisms and sites of this acceleration, in particular the roles of shock waves and magnetic reconnection. This session will discuss current observations and models of Coronal Mass Ejections, their impact on the near-Earth environs, and the radio bursts they produce. The design and deployment of proposed ν<10 MHz imaging arrays on the Moon will be presented. The arrays and their deployers also have other science applications. Examples include detection of interplanetary and interstellar dust striking polyimide antennas on the lunar surface and deployment of a range of detectors for other science targets.

304.01 – **The Current Status of Research on Coronal Mass Ejections**

Angelos Vourlidas[1]

[1]*NRL.*

10:00 AM - 10:15 AM

Coronal Mass Ejections (CMEs) are the main drivers of Space Weather and have been the focus of intense research since the mid-1990's. Since 2007, CMEs have even been studied stereoscopically by the STEREO mission. We now have observations spanning more than one solar cycle, 3D information, simultaneous remote and in-situ observations, a wide wavelength coverage, and quite sophisticated MHD simulations. In this talk, I will review our current status of knowledge on the CME phenomenon with an emphasis on the open issues on the geoeffectiveness of these events.

304.02 – **Solar Eruptions Imaged by EUV and X-Ray Telescopes**

Kathy Reeves[1]

[1]*Harvard-Smithsonian, CfA.*

10:15 AM - 10:30 AM

Solar eruptions, thought to be driven by the reconnection of magnetic fields, are the major source of space weather events at Earth. Recently developed imaging telescopes in the EUV and X-rays on the STEREO, Solar Dynamics Observatory and Hinode satellites are providing new insights into the triggering and evolution of these eruptions. In this talk, I will review recent results from these observatories, including evidence for dipolarizing magnetic field lines, observations of structures associated with current sheets, plasmoid eruptions indicative of instabilities in the plasma along the reconnected field, and possible evidence for shocks in solar flares.

304.03 – **CME-associated Radio Bursts from Satellite Observations**

Nat Gopalswamy[1]

[1]*NASA GSFC.*

10:30 AM - 10:45 AM

Coronal mass ejections (CMEs) are closely associated with various types of radio bursts from the Sun. All radio bursts are due to nonthermal electrons, which are accelerated during the eruption of CMEs. Radio bursts at frequencies below about 15 MHz are of particular interest because they are associated with energetic CMEs that contribute to severe space weather. The low-frequency bursts need to be observed primarily from space because of the ionospheric cutoff. The main CME-related radio bursts are associated are: type III bursts due to accelerated electrons propagating along open magnetic field lines, type II bursts due to electrons accelerated in shocks, and type IV bursts due to electrons trapped in post-eruption arcades behind CMEs. This paper presents a summary of results obtained during solar cycle 23 primarily using the white-light coronagraphic observations from the Solar Heliospheric Observatory (SOHO) and the WAVES experiment on board Wind. Particular emphasis will be placed on what we can learn about particle acceleration in the coronal and interplanetary medium by analyzing the CMEs and the associated radio bursts.

304.04 – **Impacts of CME energized particles on the near-Earth environment**

Daniel Baker[1]

[1]*University of Colorado.*

10:45 AM - 11:00 AM

This talk describes possible extreme space weather impacts. We demonstrate that society depends heavily on a variety of technologies that are vulnerable to the effects of intense solar storms and solar energetic particle (SEP) events. Solar storm-driven ionospheric disturbances interfere with high-frequency radio communications and navigation signals from Global Positioning System (GPS) satellites. Exposure of spacecraft to solar particles can cause temporary operational anomalies, damage critical electronics, degrade solar arrays, and blind optical systems such as imagers and star trackers. Moreover, intense SEP events present a significant radiation hazard for astronauts during the high-latitude segment of the International Space Station (ISS) orbit as well as for future human explorers of the Moon and other deep-space destinations. In addition to direct effects such as spacecraft anomalies, a thorough assessment of the impact of severe space weather events on present-day society must include the collateral effects of space-weather-driven technology failures. For example, polar cap absorption events due to solar particles can degrade - and, during severe events, completely black out - radio communications along transpolar aviation routes, requiring aircraft flying these routes to be diverted to lower latitudes. A complete picture of the impact of severe space weather therefore must include both direct as well as indirect effects on dependent infrastructures and services. We place these concerns in the context of a recent National Academies study (led by the speaker) of extreme space weather effects.

304.05 – **Heliophysics From the Surface of the Moon**

Justin C. Kasper[1]

[1]*Harvard-Smithsonian CfA.*

11:00 AM - 11:15 AM

Heliophysics, a combination of the disciplines of solar physics, space physics, and space weather, is the study of the system composed of the Sun's heliosphere and the objects that interact with it, including the moon. Heliophysics science has been tightly coupled with exploration since the beginning of the space program, as scientists work to both understand the physics of the Sun-Earth-Moon system and to develop predictive capabilities that enable operational planning for lunar, deep space, and eventually Mars missions. Renewed robotic and human exploration of the moon creates opportunities for several new classes of experiments on the lunar surface and in lunar orbit that will both provide real-time awareness of space weather conditions during manned missions and advance the field of heliophysics science. The purpose of this talk is to summarize the scientific motivations and exploration benefits of heliophysics science experiments described in the 2007 NASA report "Heliophysics Science and the Moon: Potential Solar and Space Physics Science for Lunar Exploration". A series of potential experiments will be discussed, ranging from small dust and particle sensors to sophisticated radio and optical telescopes.

304.06 – **Antenna Deployment for a Pathfinder Lunar Radio Observatory**

Robert J. MacDowall[1], F. A. Minetto[1], T. W. Lazio[2], D. L. Jones[2], J. C. Kasper[3], J. O. Burns[4], K. P. Stewart[5], K. W. Weiler[5]

[1]*NASA/GSFC,* [2]*Jet Propulsion Laboratory,* [3]*Center for Astrophysics,* [4]*University of Colorado,* [5]*Naval Research Laboratory.*

11:15 AM - 11:30 AM

A first step in the development of a large radio observatory on the moon for cosmological or other astrophysical and planetary goals is to deploy a few antennas as a pathfinder mission. In this presentation, we describe a mechanism being developed to deploy such antennas from a small craft, such as a Google Lunar X-prize lander. The antenna concept is to deposit antennas and leads on a polyimide film, such as Kapton, and to unroll the film on the lunar surface. The deployment technique utilized is to launch an anchor which pulls a double line from a reel at the spacecraft. Subsequently, the anchor is set by catching on the surface or collecting sufficient regolith. A motor then pulls in one end of the line, pulling the film off of its roller onto the lunar surface. Detection of a low frequency cutoff of the galactic radio background or of solar radio bursts by such a system would determine the maximum lunar ionospheric density at the time of measurement. The current design and testing, including videos of the deployment, will be presented. These activities are funded in part by the NASA Lunar Science Institute as an activity of the Lunar University Network for Astrophysical Research (LUNAR) consortium. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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305 – Galaxy Mergers from the Largest to the Smallest Scales: Early to Late Stages of Galaxy Mergers

Meeting-in-a-Meeting – Room 2, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

This second session looks at the actual process of galaxy merging, from the early phase of interaction to the late stage of merging and the formation of a new galaxy, and focuses on the large and small-scale gas and stellar dynamics during the merger. The first part of the session addresses theoretical aspects and numerical simulations of galaxy mergers, while the second part describes observations of the properties of galaxies in the process of merging, and signs of past mergers in the host galaxies of massive quasars.

305.01 – **Gas Dynamics in Black Hole Pairing**

Sandor Van Wassenhove[1]

[1]*University of Michigan.*

10:00 AM - 10:20 AM

When two galaxies merge, the fate of the supermassive black holes (SMBHs) originally present in each galaxy is not straightforward. If dynamical friction is effective, the two SMBHs can form a bound pair and may eventually coalesce through gravitational wave emission. We study the gas and stellar dynamics in galaxy mergers using high resolution numerical simulations to focus on the first stage: the formation of SMBH binaries. Our simulations include radiative gas cooling, star formation, SMBH accretion and feedback from supernovae and SMBHs. We resolve scales of tens of parsecs, allowing us to follow the interplay between dynamics, star formation, and accretion, and determine whether the SMBHs form a bound pair. In the early stages of galaxy mergers, when the galaxies are at separations of tens of kiloparsecs, the galaxies and their SMBHs are relatively quiescent. In the late stages, strong gas inflows drive central starburst activity and SMBH accretion. The gas dynamics and star formation in the secondary galaxy are crucial to successful SMBH pairing, especially in low mass ratio mergers, where ram pressure stripping may remove much of the gas from the secondary before the final stages of the merger. We investigate the impact of mass ratio, morphology, and gas fraction on SMBH pairing, accretion, and the incidence of dual AGN.

305.02 – **Growing the Lightest Supermassive Black Holes: Beyond the Major Merger Paradigm**

Kelly Holley-Bockelmann[1]

[1]*Vanderbilt University.*

10:20 AM - 10:40 AM

Gas-rich major galaxy mergers can easily generate the central stockpile of fuel needed for a low mass central black hole 'seed' to grow quickly and efficiently into a supermassive one. Because of the clear theoretical link between gas-rich major mergers and supermassive black hole growth, this major merger paradigm has become a well-accepted way to form billion solar mass black holes in the quasar epoch. It's much less clear, though, how well this paradigm works for growing the 'lightest' supermassive black holes; these million solar mass black holes tend to lie in Milky Way-like disk galaxies, where the supermassive black hole is currently quiescent and major mergers are few and far between. This talk will touch on some current and ongoing work on refining our theories of black hole growth for this lightest supermassive class.

305.03 – **Luminous Infrared Galaxies: Superstarbursts and Merging Massive Black Holes**

David B. Sanders[1]

[1]*Univ. of Hawaii.*

10:40 AM - 11:00 AM

Our current view of galaxy evolution has been dramatically enhanced by new deep field surveys at FIR and Submm wavelengths. Evidence now suggests that as much as 80% of the "activity" in galaxies in the distant Universe is hidden by dust. Much of this obscured activity occurs in Luminous Infrared Galaxies (LIRGs), which appear to be triggered by major mergers of gas-rich spirals. LIRGs are powered by both dust-enshrouded, super-starbursts and accretion onto massive black holes (MBH). The LIRG phase ends shortly after the merger of the two MBH, which leaves behind a gas-poor, massive elliptical galaxy. I will review current evidence which suggests that the major growth period (x100) of these merging MBH occurs during a time interval of a few hundred million years, coinciding with an ultra-luminous infrared phase when the merger nuclei are still heavily enshrouded in dust.

305.04 – **Quasars and Mergers**

Gabriela Canalizo[1], A. Stockton[2], V. Bennert[3], K. Lee[1], C. Welker[1], C. Peng[4]

[1]*Univ. of California, Riverside,* [2]*Institute for Astronomy, U. of Hawaii,* [3]*Cal Poly San Luis Obispo,* [4]*Carnegie Observatories.*

11:00 AM - 11:20 AM

The majority of luminous quasars are known to reside in centers of galaxies that appear to be ellipticals. Numerical simulations have shown that remnants of galaxy mergers often closely resemble elliptical galaxies. However, it is still strongly debated whether the majority of quasar host galaxies are indeed the result of relatively recent mergers or whether they are completely analogous to inactive ellipticals to which nothing interesting has happened recently. We discuss results from a long campaign of space- and ground-based imaging and spectroscopic observations of $z < 0.5$ quasar hosts that imply that mergers are indeed essential for the triggering of quasar activity, and that these mergers invariably induce starbursts either during or shortly after the merger. In particular, deep HST ACS and WFPC2 images of a sample of 19 quasar host galaxies that had been previously classified as elliptical galaxies reveal striking signs of tidal interactions such as ripples, tidal tails, and warped disks. Thus, these host galaxies are the products of relatively recent merger events rather than old galaxies formed at high redshift. We perform the same analysis to a control sample of inactive elliptical galaxies with equally deep HST imaging and compare the results. Finally, we briefly discuss the differences in the stellar populations of the quasar and control samples, as inferred from modeling deep Keck absorption line spectra of their bulges.

Support for this work was provided by NASA through a grant from the Space Telescope Science Institute (programs GO-10421, GO-11101, and AR-10941), which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555, and by the National Science Foundation, under grant number AST 0507450.

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306 – Exoplanet Census from Kepler

Meeting-in-a-Meeting – Ballroom C, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

NASA's Kepler Mission is designed to determine the frequency of rocky planets in or near the habitable zone of solar-like stars. As of Jan 2012, Kepler has collected over 2 1/2 years of nearly continuous precise photometry on more than 150,000 stars. 1 1/2 years of data are available to the public, with the remainder to be released by the end of the nominal mission in Nov 2012. Over 2300 transiting planet candidates have been identified, a number of which are in habitable zone orbits. This session will

present the current the status of the Kepler mission, the status of the exoplanet search, and the status of follow-up observations. Talks will cover specific classes of exoplanets and exoplanet systems, giving their characteristics, prevalence, and distributions. Both theory and observational talks will cover Earth-size and sub-Neptune-size planets, giant planet characterization, multiple planet systems, and the dynamics of planetary systems.

306.01 – **Transiting Planet Candidates Observed by Kepler**

Natalie M. Batalha[1], Kepler Team

[1]*San Jose State University.*

10:00 AM - 10:12 AM

Transiting planet candidates have been identified in sixteen months (May 2009 - September 2010) of data from the Kepler spacecraft. The characteristics of the current catalog will be described. Nearly five thousand periodic transit-like signals were vetted against astrophysical and instrumental false positives, yielding 1,092 new viable candidates, bringing the total count up to over 2,300. Improved vetting metrics have produced higher catalog reliability. Most notable is the noise-weighted robust averaging of multi-quarter photo-center offsets derived from difference image analysis which identifies likely background eclipsing binaries. The gains in the number of the smallest planet candidates are larger than expected from improved Poisson statistics and a broader window function and demonstrate the benefit of continued development of pipeline analysis software. The fraction of all host stars with multiple candidates has grown from 17% to 20%, and the paucity of short-period giant planets in multiple systems is still evident. A clear trend toward smaller planets at longer orbital periods with each new catalog release suggests that earth-size planets in the habitable zone are forthcoming if, indeed, such planets are abundant. Progress toward the next catalog release will be described as well as the strategies for the remainder of Kepler's baseline mission.

306.02 – **Planet Masses and Densities**

Geoffrey W. Marcy[1]

[1]*UC, Berkeley.*

10:12 AM - 10:24 AM

The masses of Kepler planet candidates remain unknown until some dynamical technique measures the gravitational effect of that planet on either the star (with RV measurements) or other planets (with TTVs). Measuring planet masses is particularly important as, when combined with the transit-based planet radii, they yield the bulk density of the planets, constraining conditions in the interior, notably the amount of metal, rock, water, and gas. For planets smaller than 2 Earth-radii, the transition from Neptune-like to rocky planets is particularly intriguing, bearing on formation, evolution, and habitability. We report precise (2 m/s) Doppler RVs for 15 host stars of Kepler planet candidates. New RV techniques are now employed for faint stars of 13th mag, notably long-slit sky subtraction and statistical priors for the PSF and wavelength scale in the Doppler analysis. The RV observations are timed at moments near orbital quadrature to maximize the RV differences. We obtained 10-20 RVs for each of 15 host stars of Kepler planet candidates, with typical exposure times of 30 min. The RVs are fit with Keplerian models that include all transisting planets and their known ephemerides from the Kepler photometry. The two free parameters are only the masses of the planets and RV zero point. Both random and systematic errors will not be correlated with orbital phase, ensuring that the RV signal-to-noise improves as the square root of the number of RV observations. Orbital fits provide planet mass, density, and in some cases contraints on eccentricity. For RV non-detections, MCMC analyses provide upper limits to planet mass and density.

306.03 – **Small Planets Do Not Require A Metal-Rich Environment**

David W. Latham[1], L. A. Buchhave[2]

[1]*Harvard-Smithsonian, CfA,* [2]*Niels Bohr Institute, University of Copenhagen, Denmark.*

10:24 AM - 10:36 AM

The abundance of heavy elements (metallicity) in the photospheres of stars similar to the Sun provides a fossil record of the chemical composition of the initial protoplanetary disc. Metal-rich stars are much more likely to harbor gas giant planets, thereby supporting the core accretion scenario of planet formation. However, whether the exoplanet-metallicity relationship extends into the terrestrial planet regime is unknown, but important for a better understanding of planet-formation processes. The unprecedented photometric sensitivity of the Kepler mission provides the first opportunity to probe the metallicities of a statistically significant number of stars hosting small planets. Here we report spectroscopic metallicities of the host stars of 226 exoplanet candidates discovered by Kepler. We find that, contrary to gas giants, the detection of small planets does not depend as strongly on the metallicity of the host star: Planets smaller than 4 Earth radii form around host stars with a wide range of metallicities.

306.04 – **Characteristics of the Stars and Exoplanets in Multiple Planet Systems from Kepler**

David Ciardi[1], Kepler Team

[1]*Caltech.*

10:36 AM - 10:48 AM

Kepler has shown that multiple planets in single stellar systems are common. The false positive probability for the planets in multiple systems is significantly lower than that of single planet systems. We have obtained spectra for many of the stars in the multi-planet sample and determined the stellar effective temperatures, surface gravities and radii of the stars, and we have also utilized imaging to assess the blend contamination for each of the Kepler stars with multiple known planets. Coupling the derived stellar parameters and the deblended light curves, we have characterized size distributions of the planets, and we present a statistical characterization of these multiple systems.

306.05 – **Dynamics of Kepler's Multiple Planet Systems**

Jack J. Lissauer[1], Kepler Science Team

[1]*NASA Ames Research Center.*

10:48 AM - 11:00 AM

Among the ~1800 Kepler targets that have candidate planets, 20% have two or more candidate planets. While most of these objects have not yet been confirmed as true planets, several considerations strongly suggest that the vast majority of these multi-candidate systems are true planetary systems. Virtually all candidate systems are stable, as tested by numerical integrations (assuming a nominal mass-radius relationship). Statistical studies performed on these candidates reveal a great deal about the architecture of planetary systems, including the typical spacing of orbits and flatness of planetary systems. The distribution of observed period ratios shows that the vast majority of candidate pairs are neither in nor near low-order mean motion resonances. Nonetheless, there are small but statistically significant excesses of candidate pairs both in resonance and spaced slightly too far apart to be in resonance, particularly near the 2:1 resonance.

306.06 – **Confirming and Constraining Kepler Planets via Transit Timing Variations**

Matthew J. Holman[1], Kepler Team

[1]*Harvard-Smithsonian Center for Astrophysics.*

11:00 AM - 11:12 AM

Roughly 2,000 Kepler planet candidates have been reported to date, a significant fraction of which are in systems with multiple transiting planet candidates. In some cases, the signature of the gravitational interactions between planets in these systems can be seen in the variations of their times of transit. By carefully modeling the transit times, as well as investigating the long-term stability, we are able to measure or constrain the masses and orbits of the transiting bodies in these systems, verifying that they are indeed planets. Although this approach is particularly effective for closely packed and near-resonant systems, it has also been applied to a broad range of systems. These include circumbinary planets, as well as systems with additional non-transiting planets. We review the process of using transit timing variations to confirm Kepler planets, including an estimate of the number of planets we expect to confirm with this technique. In particular, we discuss the prospects of confirming Kepler planets in the habitable zones of their host stars.

306.07 – **Recent Kepler Results on Candidate Circumbinary Planets**

Jerome A. Orosz[1], W. F. Welsh[1], Kepler Team

[1]*San Diego State University.*

11:12 AM - 11:24 AM

We present a progress report on our efforts to find circumbinary planets in eclipsing binaries (EBs), both transiting and non-transiting. In the transiting cases, small dips due to a planetary transit occur at irregular intervals, and in many cases these can be found after a careful visual inspection of the light curve. If the planet is in a relatively close orbit about the EB, it can induce small period changes in the binary. These small period changes in turn cause the eclipse times to deviate slightly from a simple linear ephemeris. Kepler has been monitoring over two thousand EBs for three years. We have measured accurate eclipse times for about 1100 of these EBs in order to search for small timing variations that could be due to a planet in the system. We will discuss the latest results on Kepler-16, Kepler-34, and Kepler-35, along with several additional candidate 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 also acknowledge support from the Kepler Participating Scientists Program via NASA grant NNX08AR14G.

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307 – Black Holes, Accretion Disks and Gravitational Waves

Oral Session – Ballroom B, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

307.01 – **Evidence for Collimated Outflow from Sgr A*?**

Farhad Yusef-Zadeh[1], R. Arendt[2], H. Bushouse[3], W. Cotton[4], D. Haggard[1], C. Heinke[5], D. A. Roberts[1], M. Royster[1], M. Wardle[6]

[1]*Northwestern Univ.,* [2]*GSFC,* [3]*STScI,* [4]*NRAO,* [5]*U. Alberta, Canada,* [6]*Macquarie U., Australia.*

10:00 AM - 10:10 AM

The compact radio source Sgr A* is considered to be coincident with a 4 million solar mass black hole at the dynamical center of the Galaxy. There has been a considerable debate as to whether the jet or the accretion flow model can explain the broad band spectrum of the emission. Here, we present high resolution radio, X-ray continuum and FeII line images showing new structural details within the inner arcminute (2.4pc) of Sgr A*. On a small scale, we find a chain of radio blobs which appear to be emanating from Sgr A*. These blobs are detected beyond the

inner 1" of Sgr A* and are distributed along a continuous linear feature that is tilted by 28 degrees with respect to the Galactic plane. In linear polarization images at 3.6cm, three blobs of emission have been detected symmetrically about 1' from Sgr A*. The morphology and polarization of the linear feature suggest a jet outflow from Sgr A*, punching through the orbiting ionized gas and producing X-ray emission as well as a hot bubble of FeIII/FeII line emission. On a scale of about 15pc, we also note a collection of large-scale radio and X-ray "streamers" in the direction perpendicular to the Galactic plane. This complex structure consists of nonthermal and thermal continuum features as well as molecular clouds traced at infrared wavelengths. The base of the outflowing gas appears to be confined by the 2-pc molecular ring, within which a cluster of massive stars lie. These features suggest star-burst driven outflow may be responsible for this energetic activity.

307.02 – **Launching and Quenching of Black Hole Relativistic Jets**

Hung-Yi Pu[1], K. Hirotani[2], H. Chang[3]

[1]*Physics Department, National Tsing Hua University, Taiwan,* [2]*Theoretical InstituteforAdvancedResearchinAstrophysics(TIARA), AcademiaSinica, Instituteof AstronomyandAstrophysics (ASIAA), Taiwan,* [3]*Institute of Astronomy, National Tsing Hua University, Taiwan.*

10:10 AM - 10:20 AM

The energy source of relativistic jets from accreting black holes is believed to be the rotational energy of the black holes. However, it remains unanswered why the jets are quenched when the accretion rate exceeds a certain limit; that is, when the disk luminosity exceeds about 1 percent of Eddington luminosity. Because the accretion environment, namely that the type of accretion disks, varies with the accretion rate, the solution to this open question is likely associated with the changing of the magnetohydrodynamic (MHD) inflow property near the black hole, which directly relates to the MHD extraction of the black hole's rotational energy. By investigating whether the 'MHD Penrose process', which enables the MHD extraction of the hole's energy and hence the launching of relativistic jets, can operate when the inflow properties are altered by a disk of a specific type, we explain the observed launching and quenching of black hole relativistic jets and propose a new paradigm of disk-jet couplings for both black hole X-ray binaries and active galactic nuclei.

307.03 – **Using HST to Detect Isolated Black Holes and Neutron Stars through Astrometric Microlensing**

Kailash C. Sahu[1], M. Albrow[2], J. Anderson[1], H. E. Bond[1], I. Bond[3], T. M. Brown[1], S. Casertano[1], M. Dominik[4], H. C. Ferguson[1], C. Fryer[5], M. Livio[1], S. Mao[6], Y. Perrott[7], A. Udalski[8], P. Yock[9]

[1]*STScI,* [2]*Univ. Canterbury, New Zealand,* [3]*Massey University, New Zealand,* [4]*University of St Andrews, United Kingdom,* [5]*Los Alamos National Laboratory,* [6]*Manchester University, United Kingdom,* [7]*University of Cambridge, United Kingdom,* [8]*Warsaw University, Poland,* [9]*Univ. Auckland, New Zealand.*

10:20 AM - 10:30 AM

To date, Black Hole (BH) and Neutron Star (NS) masses have been directly measured only in binaries; no isolated stellar-mass BH has been detected unambiguously within our Galaxy. We have underway a large, 3-year HST program (192 orbits) designed to detect microlensing events caused by non-luminous isolated BHs and NSs in the direction of the Galactic bulge. Our program consists of monitoring of 12 fields in the Sagittarius window of the Galactic bulge, containing a total of ~1.5 million stars down to V=28. Our observations have a typical cadence of one observation every two weeks, and are primarily targeted towards detecting microlensing events caused by non-luminous isolated BHs and NSs in the Galactic disk and bulge.

The unique capability of HST imaging for microlensing observations is the addition of high-precision astrometry, allowing detection of the astrometric shift of the source during the event. Combined with the lens parallax, which can be determined from the light curve as measured by HST (and supplemented by GEMINI) observations, the astrometric shift provides a direct measurement of the lens mass. Our program is optimized to detect long-duration events, which are more likely to be caused by massive lenses. We expect to detect a few dozen long-duration microlensing events, of which 45% will show astrometric deflections, leading to direct determinations of the lens masses.

307.04 – **The Microlensing Signature of Binary Black Holes**

Jeremy Schnittman[1], T. Littenberg[2], K. Sahu[3]

[1]*NASA/GSFC,* [2]*U. Maryland and NASA/GSFC,* [3]*STScI.*

10:30 AM - 10:40 AM

We calculate the light curves of galactic bulge stars magnified via microlensing by stellar-mass binary black holes along the line-of-sight. We show the sensitivity to measuring various lens parameters for a range of survey cadences and photometric precision. Using public data from the OGLE collaboration, we identify two candidates for massive binary systems, and discuss implications for theories of star formation and binary evolution. Upcoming astrometric measurements with the Hubble Space Telescope will break several fundamental model degeneracies, further improving our confidence in the discovery of binary black holes.

307.05 – **The Chandra Legacy 1 Megasecond Observation of NGC3115**

Jimmy Irwin[1], K. Wong[1], J. Strader[2], A. Romanowsky[3], G. Sivakoff[4], M. Yukita[1], E. Million[1], Y. Su[1], W. Mathews[3], E. Quataert[5], J. Brody[3], S. Larsen[6]

[1]*University of Alabama,* [2]*SAO,* [3]*University of California-Santa Cruz,* [4]*University of Alberta, Canada,* [5]*University of California-Berkeley,* [6]*University of Utrecht, Netherlands.*

10:40 AM - 10:50 AM

We present initial results from the Chandra 1 Megasecond observation of the nearby S0 galaxy NGC3115, which harbors the nearest >1e9 solar mass supermassive black hole. The goal of this legacy-type project is to put the first direct observational constraints on the temperature and density structure of an accretion flow inside the Bondi radius of a supermassive black hole. These temperature/density constraints will provide a critical test for competing inefficient accretion flow theories. The large angular Bondi radius of NGC3115's black hole provides the *only* opportunity to perform such a test of inefficient accretion flow theory in the Chandra era and the foreseeable future. In addition to providing temperature and density profiles of the hot gas, this long observation also represents the deepest look at the X-ray binary population of a normal early-type galaxy.

307.06 – **X-ray Reflected Spectra from Accretion Disks: The Impact of Ionization Gradients**

Javier Garcia[1], C. Reynolds[1], J. McClintock[2], T. Kallman[3]

[1]*University of Maryland,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*NASA - Goddard Space Flight Center.*

10:50 AM - 11:00 AM

Reflection models from accretion disks are a key component in the interpretation of the X-ray spectra from compact accreting sources. These are used to constrain important physical information about the disk itself, such as the degree of ionization of the material, elemental abundances, and the distance of the inner-edge of the accretion disk to the compact object. The latter can ultimately be used to derive the spin of the black hole. However, fits with current models rely on the assumption that the reflecting region of the disk responsible for the observable spectral features is at one particular ionization state, despite the fact that this region can sometimes be considered to extend up to several hundreds of gravitational radii. We present the construction of a more elaborated model in which we consider a gradient of ionization along the radial direction in the accretion disk. We then combine several single ionization reflection models which are integrated taking into account the effective area of the reflector and the viewing angle to produce one single reflection model. We show the effect of considering an ionization structure in the synthetic spectra and the impact on the interpretation of the observable data. We also discuss how these models can affect the inferred physical properties from accreting sources. This has important implications on the derivation of fundamental quantities such as the abundance of atomic iron and the spin parameter of the black hole.

307.07 – **Fast and Accurate Sky Localization of Gravitational Wave Sources using MCMC Methods**

Benjamin F. Farr[1], V. Raymond[1], W. Farr[1], D. Fazi[1], J. Veitch[2], I. Mandel[3], B. Aylott[3], C. Roever[4], V. Kalogera[1]

[1]*Northwestern University,* [2]*Nikhef - National Institute for Subatomic Physics, Netherlands,* [3]*University of Birmingham, United Kingdom,* [4]*Max-Planck-Institut fur Gravitationsphysik, Germany.*

11:00 AM - 11:10 AM

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. We have repurposed 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. In order to produce sky maps at low-latency, we use non-Markovian techniques that can, in principle, cause deviations in the recovered sky map. We present a systematic comparison of approximate sky maps produced using these methods to the robust maps produced by full MCMC analyses.

307.08 – **Transient Gravitational-wave Astronomy With LIGO, Virgo And GEO600**

Joshua Smith[1], LIGO Scientific Collaboration, Virgo Collaboration

[1]*California State University Fullerton.*

11:10 AM - 11:20 AM

Most of our astronomical knowledge comes from light. Gravitational waves present a new and fundamentally different spectrum in which to observe the universe. The first generation international network of ground based laser interferometeric detectors (LIGO, Virgo, and GEO600) recently completed several years of joint observation. This data has been searched for signatures of gravitational radiation from various sources including stochastic sources, spinning isolated neutron stars, burst sources such as supernovae, and coalescence of compact binary systems. I will present the results from the latest searches for burst and compact binary coalescence sources. I will also present prospects for detection in the advanced detector era to begin around 2015.

307.09 – **Swift Follow-up Observations of Candidate Gravitational-Wave Transient Events**

Ruslan Vaulin[1], LIGO and Virgo Scientific Collaboration, P. A. Evans[2], N. Gehrels[3], J. Gelbord[4], P. Handbauer[5], J. A. Kennea[4], J. P. Osborne[2], M. Siegel[6], M. Smith[4]

[1]*MIT,* [2]*University of Leicester, United Kingdom,* [3]*NASA Goddard Space Flight Center,* [4]*Pennsylvania State University,* [5]*Eotvos Lorand University, Hungary,*

[6]*Pennsylvania State University,.*
11:20 AM - 11:30 AM

We present latest results of the low-latency follow-up observations by Swift of candidate gravitational-wave (GW) transient events identified by the LIGO-Virgo detector network during two observing periods in 2009-2010 science runs. Observations were performed as a part of collaborative program to search for electromagnetic (EM) counterparts to GW candidate events between LIGO-Virgo and partner optical and X-ray telescopes. We performed the first joint analysis of GW and EM data that allows us to cast results into a combined statement. We discuss implications of the joint observations with LIGO-Virgo and Swift in terms of sensitivity of the current and future searches for gravitational-wave transients.

308 – Starbursts & Spirals

Oral Session – Room 1, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

308.01 – **The Gismo 2-millimeter Deep Field In GOODS-N**

Johannes Staguhn[1], A. Kovacs[2], F. Walter[3], E. Dwek[4], R. Decarli[3], D. Benford[5], D. Fixsen[6], K. Irwin[7], C. Jhabvala[5], S. Samuel Leclercq[8], S. Maher[5], T. Miller[5], S. Moseley[5], E. Sharp[5], E. Wollack[5]

[1]*Johns Hopkins University & NASA's GSFC,* [2]*Caltech,* [3]*Max Planck Institute for Astronomy, Germany,* [4]*Nasa/ Goddard Space Flight Center,* [5]*NASA/Goddard Space Flight Center,* [6]*University of Marylanf,* [7]*National Institute of Standards and Technology,* [8]*IRAM, France.*
10:00 AM - 10:10 AM

We present results from our 2 millimeter deep continuum observations centered on the Hubble Deep Field (HDF) in the GOODS-N field.

308.02 – **Discovery of an Exceptionally Bright Gravitationally Lensed Submillimeter Galaxy at z=4.69**

Eiichi Egami[1], Herschel Lensing Survey (HLS) team

[1]*Univ. of Arizona.*
10:10 AM - 10:20 AM

We report the discovery of an exceptionally bright gravitationally lensed submillimeter galaxy at z=4.69. Through our on-going Herschel survey of gravitationally lensed high-redshift galaxies in the fields of massive galaxy clusters ("The Herschel Lensing Survey (HLS)" - PI: Egami), we identified in the field of a z=0.3 cluster a bright Herschel/SPIRE source (~100 mJy at 500 um) whose far-infrared/submillimeter spectral energy distribution is peaking toward 500 um, indicating that its redshift is likely above 4. The APEX/LABOCA 870 um image showed that this source is not only bright (60 mJy at 870 um) but also spatially extended even with the LABOCA resolution of ~20'', although it is invisible in the HST/ACS F606W image. The spectroscopic redshift came from the IRAM30m/EMIR observations, which detected the CO(4-3) and CO(5-4) lines with the corresponding redshift of 4.69. The high-resolution (beam=0.8"x0.7") SMA 345 GHz map has subsequently resolved this source into four components, which are likely four lensed images of the same background galaxy. This lensing interpretation has been confirmed by the HST WFC3/IR observations, which not only revealed the same morphology for the multiple sources but also detected the 5th image at the predicted location. We therefore conclude that this lensed system exhibits a rare hyperbolic umbilic image configuration, which produces a large magnification factor of x100-200 when the four components are combined. What is even more remarkable is that the four HST sources are not spatially coincident with the four SMA sources. In other words, this z=4.69 galaxy appears to consist of two spatially distinct components, one of which (the one responsible for the bright IR/submm emission) is completely invisible in the HST near-infrared images. This suggests that there may exist a population of dust-obscured galaxies at z>4 that are hidden from our deep optical/near-infrared view.

308.03 – **The Source Counts of Submillimeter Galaxies Detected at λ = 1.1 mm**

Kimberly S. Scott[1], G. W. Wilson[2], I. Aretxaga[3], J. E. Austermann[4], E. L. Chapin[5], J. D. Dunlop[6], H. Ezawa[7], M. Halpern[5], B. Hatsukade[8], D. H. Hughes[3], R. Kawabe[9], S. Kim[10], K. Kotaro[11], J. D. Lowenthal[12], A. Montana[3], K. Nakanishi[7], T. Oshima[9], D. Sanders[13], D. Scott[5], N. Scoville[14], Y. Tamura[11], D. Welch[2], M. S. Yun[2], M. Zeballos[3]

[1]*North American ALMA Science Center, National Radio Astronomy Observatory,* [2]*University of Massachusetts,* [3]*Instituto Nacional de Astrofisica, Optica y Electronica, Mexico,* [4]*Center for Astrophysics and Space Astronomy, University of Colorado,* [5]*University of British Columbia, Canada,* [6]*University of Edinburgh, Royal Observatory, United Kingdom,* [7]*ALMA Project Office, National Astronomical Observatory of Japan, Japan,* [8]*Kyoto University, Japan,* [9]*Nobeyama Radio Observatory, National Astronomical Observatory of Japan, Japan,* [10]*Sejong University, Korea, Republic of,* [11]*Institute of Astronomy, University of Tokyo, Japan,* [12]*Smith College,* [13]*University of Hawaii,* [14]*California Institute of Technology.*
10:20 AM - 10:30 AM

The source counts of galaxies discovered at sub-millimeter and millimeter wavelengths provide important information on the evolution of infrared-bright galaxies. We combine the data from six blank-field surveys carried out at 1.1 mm with AzTEC, totalling 1.6 deg^2 in area with root-mean-square depths ranging from 0.4 to 1.7 mJy, and derive the strongest constraints to date on the 1.1 mm source counts at flux densities S_{1100} = 1-12 mJy. Using additional data from the AzTEC Cluster Environment Survey to extend the counts to S_{1100} ~ 20 mJy, we see tentative evidence for an enhancement relative to the exponential drop in the counts at S_{1100} ~ 13 mJy and a smooth connection to the bright source counts at >20 mJy measured by the South Pole Telescope; this excess may be due to strong lensing effects. We compare these counts to predictions from several semi-analytical and phenomenological models and find that for most the agreement is quite good at flux densities >4 mJy; however, we find significant discrepancies (>3sigma) between the models and the observed 1.1 mm counts at lower flux densities, and none of them are consistent with the observed turnover in the Euclidean-normalised counts at S_{1100} < 2 mJy. Our new results therefore may require modifications to existing evolutionary models for low luminosity galaxies. Alternatively, the discrepancy between the measured counts at the faint end and predictions from phenomenological models could arise from limited knowledge of the spectral energy distributions of faint galaxies in the local Universe.

308.04 – **Some Updates on the Star Formation Laws in Galaxies**

Yu Gao[1]

[1]*Purple Mountain Observatory, China.*
10:30 AM - 10:40 AM

We highlight some of our recent studies on the global star formation laws in galaxies. 1) We show that the surface density of dense molecular gas (traced by HCN) has the tightest linear correlation with that of star formation rate (SFR). There is no unique slope between the surface densities of SFR and total gas, using a large sample of over 150 galaxies including (ultra)luminous IR galaxies [(U)LIRGs]. The correlation slopes change from ~1 for normal spirals to ~1.5 when more and more (U)LIRGs are included. 2) Our observations using other dense gas tracer like CS further reveal that the SFR and dense gas relationship is linearly in all galaxies observed so far. 3) The locally resolved SFR-HCN correlation in M51 or the local star formation law in dense gas is also consistent with the globally established linear SFR-HCN correlation. These suggest that SFR depends linearly upon the mass of dense molecular gas. This is different from the traditional Kennicutt-Schmidt law that relates the total gas and SFR, which has no unique power-law slope.

308.05 – **A Simple Model for the Galactic Dynamo**

Ethan T. Vishniac[1]

[1]*McMaster University, Canada.*
10:40 AM - 10:50 AM

We consider a simple model for a galactic disk dynamo, based on locally isotropic turbulence within the disk. The disk is modeled as a flat shearing systems filled with independent isotropic eddies. The seed magnetic field is supplied by the incoherent addition of random electric fields generated by the turbulent eddies in the disk. The field is driven by the global flux of magnetic helicity and grows rapidly approaching saturation within a few rotations of the disk.

308.06 – **Rejuvenation of Bulges by Bars: Evidence from Stellar Population Analysis**

Dimitri Gadotti[1], P. Coelho[2]

[1]*European Southern Observatory, Chile,* [2]*Universidade Cruzeiro do Sul, Brazil.*
10:50 AM - 11:00 AM

We obtained mean stellar ages via spectrum fitting for a sample of 575 bulges with spectra available from the SDSS. Using the whole sample, where galaxy stellar mass distributions for barred and unbarred galaxies are similar, we find that the distribution of bulge ages in barred galaxies shows an excess of populations younger than 4 Gyr, when compared to bulges in unbarred galaxies. KS statistics confirm that the age distributions are different with a significance of 99.94%. If we select sub-samples for which the bulge stellar mass distributions are similar for barred and unbarred galaxies, this excess vanishes for galaxies with low-mass bulges, while for more massive bulges we find a bimodal stellar age distribution for barred galaxies only, corresponding to two normal distributions with mean ages of 10.4 and 4.7 Gyr. We also find twice as much AGN among barred galaxies, as compared to unbarred galaxies, for low-mass bulges. By combining a large sample of high-quality data with sophisticated image and spectral analysis, we are able to find evidence that the presence of bars affects the mean stellar ages of bulges. This lends strong support to models in which bars trigger star formation activity in the centers of galaxies.

This work was co-funded under the Marie Curie Actions of the European Commission (FP7-COFUND).

308.07D – **Ionized Gas Velocities from Multi-Slit Spectroscopy for Nearby, Edge-on Galaxies**

Catharine J. Wu[1], R. Walterbos[1], M. Patterson[1], R. Rand[2], G. Heald[3], HALOGAS Team

[1]*New Mexico State University,* [2]*University of New Mexico,* [3]*ASTRON, Netherlands.*
11:00 AM - 11:20 AM

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 an overview of our H-alpha observations and modeling of the ionized extra-planar gas for our sample of 12 edge-on, spiral galaxies, several of which are HALOGAS (Hydrogen Accretion in LOcal GAlaxieS) targets. 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 H-alpha emitting gas as a function of height above the disk in 11 radial distance bins in a single exposure. The goal of this project is to characterize the kinematics of extra-planar ionized gas, measure a vertical velocity gradient for targets that show a lagging component, and compare the characteristics of neutral and ionized extra-planar hydrogen gas.

308.08 – **X-ray Spectroscopy of Galactic Feedback**

Q. Daniel Wang[1]
[1]*Univ. of Massachusetts.*
11:20 AM - 11:30 AM

Diffuse soft X-ray line emission has commonly been used to trace various types of galactic feedback in galaxies. But the exact origins of this emission remain largely uncertain. We have analyzed XMM-Newton RGS spectra of nearby non-AGN galaxies, including both starburst and normal ones. In particular, we have found that the Kalpha triplet of OVII shows that the resonance line is typically weaker than the forbidden and/or inter-combination lines. This suggests that a substantial fraction of the emission may not arise directly from optically thin thermal plasma, as commonly assumed, and may instead originate at its interface with neutral gas via charge exchange. This latter origin naturally explains the observed spatial correlation of the emission with various tracers of cool gas in some of the galaxies. We are also examining alternative scenarios, such as the resonance scattering by the plasma and the relic photo-ionization by AGNs in the recent past, which cannot yet be ruled out, at least in some cases. We will further report results from an analysis of the OVII Kalpha line centroids of the Galactic diffuse X-ray background, as observed with Suzaku in various regions. Such X-ray spectroscopic studies are important to the understanding of the relationship of the emission to various high-energy feedback processes in galaxies.

309 – Solar Dynamics Observatory I

Oral Session – Room 5, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

309.01 – **CME's - The Early Stages**

Alan M. Title[1]
[1]*Lockheed Martin.*
10:00 AM - 10:15 AM

The Atmospheric Imaging Assembly on the Solar Dynamics Observatory provides 24/7 full Sun coverage with a 12 second cadence with images that span the temperature range from 6000 to 20,000,000 with arc second resolution. With this data set and observations with the pair of STEREO satellites and images from LASCO on SOHO it has become possible to identify the earliest stages of a CME and to obtain at least a rough idea of the CME's shape. Numerous example of events will be shown.

309.02 – **SDO-AIA Response Functions: Insights and Updates from Hinode EIS Bright Point Data**

Joan T. Schmelz[1], B. S. Jenkins[1]
[1]*Univ. of Memphis.*
10:15 AM - 10:30 AM

The Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory is a state-of-the-art imager with the potential to do unprecedented time-dependent multithermal analysis at every pixel on scales short compared to the radiative and conductive cooling times. Recent results, however, have identified shortcomings in the CHIANTI atomic physics data base, which is used to construct the instrument response functions. We have done Differential Emission Measure analysis using simultaneous AIA and Hinode EIS observations of six X-ray bright points. Our results not only support the conclusion that CHIANTI is incomplete near 131 A, but more importantly, suggest that the peak temperature of the Fe VIII ionization fraction is likely to be closer to Log T = 5.8 than to the current value of Log T = 5.7. Using a revised ionization balance calculation for Fe VIII, we find that the observed AIA 131-A flux can be underestimated by ~1.25, which is smaller than previous comparisons. Making these adjustments brings not only the AIA 131-A data but also the EIS Fe VIII lines into better agreement with the remainder of the bright point data. In addition, we find that CHIANTI is reasonably complete in the AIA 171- and 193-A bands.

309.03 – **Can We Resolve Coronal Loops with Hinode and SDO?**

Ignacio Ugarte-Urra[1], D. H. Brooks[1], H. P. Warren[2]
[1]*George Mason University,* [2]*Naval Research Laboratory.*
10:30 AM - 10:45 AM

A combination of spectral data from the Hinode EUV Imaging Spectrometer (EIS) and high resolution imaging from the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA) are used to investigate the fundamental spatial scales of coronal loops. We construct multi-isothermal thread models and find that we are able to successfully reproduce the cross-loop intensity profiles observed by EIS and AIA. The models allow us to set constraints on the number of threads needed to reproduce a particular loop structure, and the results suggest that although most coronal loops remain unresolved, current instruments are close to resolving them. We discuss implications for future high resolution EUV spectral imaging instruments.

309.04 – **Nanoflare Properties throughout Active Regions: Comparing SDO/AIA Observations with Modeled Active Region Light Curves**

Nicholeen Viall[1], J. Klimchuk[1]
[1]*NASA Goddard Space Flight Center.*
10:45 AM - 11:00 AM

Coronal plasma in active regions is typically measured to be at temperatures near ~1-3 MK. Is the majority of the coronal plasma in hydrostatic equilibrium, maintained at these temperatures through a form of quasi-steady heating, or is this simply a measure of the average temperature of widely varying, impulsively heated coronal plasma? Addressing this question is complicated by the fact that the corona is optically thin: many thousands of flux tubes which are heated completely independently are contributing to the total emission along a given line of sight. There is a large body of work focused on the heating of isolated features - coronal loops - which are impulsively heated, however it is the diffuse emission between loops which often comprises the majority of active region emission. Therefore in this study we move beyond isolated features and analyze all of the emission in an entire active region from all contributing flux tubes. We investigate light curves systematically using SDO/AIA observations. We also model the active region corona as a line-of-sight integration of many thousands of completely independently heated flux tubes. The emission from these flux tubes may be time dependent, quasi-steady, or a mix of both, depending on the cadence of heat release. We demonstrate that despite the superposition of randomly heated flux tubes, different distributions of nanoflare cadences produce distinct signatures in light curves observed with multi-wavelength and high time cadence data, such as those from SDO/AIA. We conclude that the majority of the active region plasma is not maintained in hydrostatic equilibrium, rather it is undergoing dynamic heating and cooling cycles. The observed emission is consistent with heating through impulsive nanoflares, whose energy is a function of location within the active region.

This research was supported by an appointment to the NASA Postdoctoral Program at GSFC/NASA.

309.05 – **Temperature And Density Analysis Of A Coronal Loop Observed By Eis And Aia**

Joseph Plowman[1], P. Martens[1], C. Kankelborg[1], M. Ritchie[2], J. Scott[1], R. Sharma[3]
[1]*Montana State University,* [2]*University of St Andrews, United Kingdom,* [3]*Mohanlal Sukhadia University, India.*
11:00 AM - 11:15 AM

We present a combined DEM and density-sensitive line ratio analysis of a loop observed simultaneously by EIS and AIA. The DEMs are calculated using a fast new method which we also describe. The temperature and density profiles of the loop are compared to and isolated from those of the surrounding material, and these properties are fit to an analytic strand heating model developed by Martens (2010). Supported by an AIA subcontract to Montana State University.

309.06 – **Investigating the Dependency of Footpoint Temperature on Hard X-ray Energy using AIA Dispersion Spectra and RHESSI Imaging**

Claire Raftery[1], H. M. Bain[1], S. Krucker[1]
[1]*Space Science Lab, UC Berkeley.*
11:15 AM - 11:30 AM

The nature of energy deposition in solar flares remains largely a mystery. There have been many studies, analyzing the energy and temperature distributions of solar flares throughout their lifetime, though few that directly characterize the temperature distribution of flaring footpoint plasma as a function of footpoint energy. Here we will use the SDO/AIA dispersion spectra technique (Raftery et al. 2011) to identify the differential emission measure distribution of individual flaring ribbons as a function of time. We will interpret the distributions with respect to the energies observed in those footpoints using RHESSI imaging and spectroscopy techniques. In doing so, we will be directly observing the changes in the temperature response of the footpoint plasma to electron beams of varying energies.

310 – Coronal B Fields I

Oral Session – Room 4, Dena'ina Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

310.01 – **Recent Results from the Coronal Multi-Channel Polarimeter**

Steven Tomczyk[1], C. Bethge[1], S. E. Gibson[1], S. W. McIntosh[1], L. A. Rachmeler[1], H. Tian[1]
[1]*HAO/NCAR.*
10:00 AM - 10:15 AM

The Coronal Multi-Channel Polarimeter (CoMP) instrument is a ground-based filter/polarimeter which can image the solar corona at wavelengths around the emission lines of FeXIII at 1074.7 and 1079.8 nm and the chromospheric emission line of HeI at 1083.0 nm. The instrument consists of a 20-cm aperture coronagraph followed by a Stokes polarimeter and a Lyot birefringent filter with a passband of 0.14 nm width. Both the polarimeter and filter employ liquid crystals for rapid electro-optical tuning. This instrument measures the line-of-sight strength of the coronal magnetic field through the Zeeman effect and the plane-of-sky direction of

the magnetic field via resonance scattering. The line-of-sight velocity can also be determined from the Doppler shift. The CoMP has obtained daily observations from the Mauna Loa Solar Observatory for almost one year. We will present recent measurements of the polarization signatures seen with the CoMP and a comparison with models that allow us to constrain coronal structure. We also will present observations of coronal waves taken with the CoMP and discuss their implications for the heating of the solar corona and the acceleration of the solar wind.

310.02 – **The Magnetism and Dynamics of Solar Coronal Cavities**

Sarah Gibson[1]

[1]*NCAR.*

10:15 AM - 10:30 AM

Magnetism defines the complex and dynamic solar corona. We have historically been limited by the difficulty of directly measuring the magnetic fields of the corona, and have turned to observations of coronal plasma to trace out magnetic structure. In some regimes, however, it is the lack of plasma that is a significant indicator of the magnetic field. Such a case is the coronal cavity: a dark, elliptical region in which strong and twisted magnetism dwells. I will elucidate these enigmatic features using observations of coronal cavities in multiple wavelengths and from a variety of observing vantages, and show how magnetic flux rope models provide a self-consistent picture of the cavity, its sub-structure, and its dynamic evolution as a CME. Moreover, I will make use of unprecedented measurements of coronal magnetism, now being obtained by the Coronal Multichannel Polarimeter (CoMP), to demonstrate the presence of twisted magnetic fields within cavities.

310.03 – **An Explanation For Large-amplitude Longitudinal Oscillations In Prominences**

Judith T. Karpen[1], M. Luna Bennasar[2]

[1]*NASA Goddard Space Flight Center,* [2]*UMD @ NASA Goddard Space Flight Center.*

10:30 AM - 10:45 AM

Large amplitude longitudinal (LAL) oscillations, consisting of periodic motions of prominence material along a filament axis, are rare but quite dramatic. The oscillations appear to be triggered by an energetic event, such as a microflare, subflare, or small C-class flare, close to a filament. Observations reveal speeds of several tens to 100 km/s, periods of order 1 hr, damping in a few periods, and displacements that are a significant fraction of the prominence length. We have developed the first self-consistent model for these oscillations that explains the restoring force and damping mechanism. We investigated the oscillations of multiple threads in our recent simulation (Luna et al. 2012), in which they form in long, dipped flux tubes through the thermal nonequilibrium process. The oscillation properties predicted by our simulations agree with the observed LAL behavior. In addition, our analytic model for the oscillations demonstrates that the restoring force is the projected gravity in the tube. Although the period is independent of the tube length and the constantly growing mass, the motions are strongly damped by the steady accretion of mass onto the threads. These suggest that a nearby impulsive event drives the existing prominence threads along their supporting tubes, away from the heating deposition site, without destroying them. As is also the case for newly formed condensations, the subsequent oscillations occur because the displaced threads reside in magnetic concavities with large radii of curvature. Our model yields a powerful seismological method for constraining the coronal magnetic field and radius of curvature of dips. Furthermore, these results indicate that the magnetic structure is most consistent with the sheared-arcade model for filament channels. We conclude that the LAL movements represent a collective oscillation of a large number of cool, dense threads moving along dipped flux tubes, triggered by a small, nearby energetic event.

310.04 – **Observations and Magnetic Field Modeling of a Large Polar Crown Prominence**

Yingna Su[1], A. van Ballegooijen[1]

[1]*Smithsonian Astrophysical Observatory.*

10:45 AM - 11:00 AM

We focus on the structures and dynamics of a large polar crown prominence before its eruption on 2010 December 6. Combination of SDO/AIA and STEREO/EUVI allows us to see the fine structures of this prominence both at the limb and on the disk. This prominence contains two parts: active region part containing mainly horizontal threads, and quiet Sun part containing mainly vertical threads. Both EUVI and AIA observe bright features on the northern side of the filament channel, while no clear counterparts are identified on the southern side. The earlier limb observations by AIA suggest that the bright features are the lower legs of the loops that go above then join in the filament. Horn-like features seen by AIA/171 are located above the prominence vertical threads. Filament materials frequently eject horizontally from the active region part to the quiet Sun part, which results in the formation of a dense-column structure (concentration of dark vertical threads) near the border of the active region. Using the flux-rope insertion method, we create two non-linear force-free field models with highly and weakly twisted flux rope, respectively. The models are constructed based on the line-of-sight magnetograms provided by SDO/HMI. The height and location of field lines' dips in both models roughly replicate those of the observed prominence. Comparison between model and observations suggests that the bright features on the northern side of the channel are the lower legs of the field lines that turn into the flux rope. The observed horn-like features suggest that the model with weakly twisted flux rope may be a better model. However, there are also some interesting differences between models and observations. For example, the model cannot explain the existence of vertical threads nor the dense-column structure.

310.05 – **Coronal Rain Observed On-disk with He I Spectropolarimetry from DST/FIRS**

Thomas A. Schad[1], M. J. Penn[2], A. Pietarila[2]

[1]*University of Arizona/National Solar Observatory,* [2]*National Solar Observatory.*

11:00 AM - 11:15 AM

Coronal rain refers to cool, dense blobs of plasma that presumably condense near the apex of hot coronal loops and then "rain" down upon the chromosphere traveling along curved loop-like paths. Considered to be the result of a thermal instability known as "catastrophic cooling", coronal rain places constraints on heating mechanisms for coronal loops. Nearly all observational studies of coronal rain, however, have been limited to the solar limb where cooler material within hot coronal loops is more readily identified. Here, we report observations of what we interpret to be the on-disk counterpart of coronal rain. Scanned spectropolarimetric observations in the He I triplet (1083 nm) from the Facility Infrared Spectropolarimeter (FIRS) reveal highly-redshifted material displaying an acceleration along curved trajectories terminating within a large sunspot (located at N17W21). Line-of-sight velocities in the He I triplet peak near ~190 km/s, which can be consider high in relation to most coronal rain observations. This is also the largest redshift ever reported in the He I triplet. These curved loops correspond to an overarching loop structure seen in SDO/AIA anchored at its ends by a large sunspot and a group of pores. The loops observed with SDO/AIA display significant cooling as dark (EUV absorptive) blobs begin to form near the loop apex and then traverse along the same trajectories observed in the He I FIRS observations. Although the EUVI instrument of STEREO-A/SECCHI has a reduced temporal resolution compared to SDO/AIA, we are able to confidently match rain features in both spacecraft and thus stereoscopically reconstruct the three-dimensional trajectory to confirm the material is raining upon the solar surface.

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311 – Russell Prize: The Cold Dark Matter Theory of Galaxy Formation: A Status Report

Invited Session – Ballroom B, Dena'ina Center – 6/12/2012 11:40:00 AM to 6/12/2012 12:30:00 PM

311.01 – **The Cold Dark Matter Theory of Galaxy Formation: A Status Report**

Sandra M. Faber[1]

[1]*University of California, Santa Cruz.*

11:40 AM - 12:30 PM

The cold dark matter theory of galaxy formation (LCDM) was introduced roughly thirty years ago and, with the later addition of dark energy, has become the standard paradigm. This talk will review the bare bones and predictions of the theory and then describe the handful of stubborn observational contradictions that are still unresolved. Are these merely details, or are we still missing one or more fundamental elements? This talk will attempt to give an answer to these questions based on recent data and theory.

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312 – NASA Town Hall

Town Hall – Ballroom A, Dena'ina Center – 6/12/2012 12:45:00 PM to 6/12/2012 1:45:00 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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313 – Informal Science Education Engages the Public and Science Careers

Town Hall – Ballroom C, Dena'ina Center – 6/12/2012 12:45:00 PM to 6/12/2012 1:45:00 PM

CAISE, the Center for Advancement of Informal Science Education, is a resource center funded by the National Science Foundation (NSF). CAISE connects informal science education (ISE) professionals and researchers to the knowledge and people of ISE, through its website, products and in-person workshops and meetings.

The Town Hall will focus both on how CAISE and the NSF can help researchers strategize their engagement with the public as well as focusing on introducing the AAS audience to the landscape of the ISE field and the diversity of career paths within it.

A growing body of research shows that people learn the majority of their science knowledge outside of school (Falk & Dierking, 2010). As a result, ISE can be an effective conduit for meaningful science communication. The Town Hall will present examples

of how the ISE field offers researchers possible non-research career options that make an impact on the publicâ€™s engagement with science.
The CAISE Town Hall will outline the diversity of the ISE field, concisely presenting data relevant to the impact of ISE on science learning. Examples of successful programs that connect AAS-related science with the public will be shared while discussing ways to bring together AAS-related researchers with practitioners and researchers within ISE. Pathways to various resources in the form of current CAISE initiatives will be described as well, including information regarding NSF awards.
The format for this Town Hall has been used at a number of meetings in the past. It includes presentations and interviews with scientists, educators and professionals involved in AAS-relevant ISE initiatives around the country as well as with those who have made the leap from a research to ISE career. The goal is conversation in a â€œtalk showâ€ format, not a panel. Ample time throughout will be allowed for discussion regarding participant programs and issues related to the ISE field.

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314 – Bridging Laboratory and Astrophysics: Dust and Ice

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying dust and ice processes which drive our cosmos.

314.01 – **Laboratory Needs for Interstellar Ice Studies**

Abraham C. A. Boogert[1]
[1]*California Institute of Tech..*
2:00 PM - 2:30 PM

A large fraction of the molecules in dense interstellar and circumstellar environments is stored in icy grain mantles. The mantles are formed by a complex interplay between chemical and physical processes. Key questions on the accretion and desorption processes and the chemistry on the grain surfaces and within the icy mantles can only be answered by laboratory experiments. Recent infrared (2-30 micron) spectroscopic surveys of large samples of Young Stellar Objects (YSOs) and background stars tracing quiescent cloud material have shown that the ice band profiles and depths vary considerably as a function of environment. Using laboratory spectra in the identification process, it is clear that a rather complex mixture of simple species (CH3OH, CO2, H2O, CO) exists even in the quiescent cloud phase. Variations of the local physical conditions (CO freeze out) and time scales (CH3OH formation) appear to be key factors in the observed variations. Sublimation and thermal processing dominate as YSOs heat their environments. The identification of several ice absorption features is still disputed. I will outline laboratory work (e.g., on salts, PAHs, and aliphatic hydrocarbons) needed to further constrain the ice band identification as well as the thermal and chemical history of the carriers. Such experiments will also be essential to interpret future high spectral resolution SOFIA and JWST observations.

314.02 – **What Do We Know About the Ultraviolet Extinction Curve, Fifty Years After the Discovery of the Bump?**

Geoffrey C. Clayton[1]
[1]*Louisiana State Univ..*
2:30 PM - 3:00 PM

It is almost 50 years since Ted Stecher reported the discovery of the 2175 A bump, and almost 25 years since CCM characterized the UV extinction curve as a one-parameter function of R(V), the ratio of total-to-selective extinction. Great strides have been made since then in laboratory, theory, and observation but many questions still remain. The bump is still an unidentified feature, and CCM is not a reliable guide to the wavelength dependence of dust extinction beyond the Milky Way. In fact, the average extinction curve of SMC dust, which has little or no evidence for a 2175 A bump, may be more common in extragalactic environments than Milky Way type dust. The UV extinction curve has been extended to the Lyman limit without any sign in a turnover in the far-UV rise. The old standbys, silicates, graphite, amorphous carbon, and PAH's are still the go-to grain types. But many questions remain about how global properties such as metallicity may lead to large variations in the extinction properties from one galaxy to another. Also of great interest is how dust grains are created, evolve and are destroyed, and in particular, what fraction comes from sources such as evolved stars and supernovae, and what fraction is grown in the ISM. I plan to summarize the role of laboratory and theory can play in better understanding the interstellar dust grains responsible UV extinction.

314.03 – **On the Formation of Astrobiologically Important Molecules in Outer Solar System Ices**

Ralf-Ingo Kaiser[1]
[1]*University of Hawaii.*
3:00 PM - 3:30 PM

The prime directive of our research project is to comprehend the chemical evolution of the Solar System and how life began and developed on Earth. This will be achieved by understanding the formation of carbon-, hydrogen-, oxygen-, and nitrogen-bearing (CHON) molecules in ices of Kuiper Belt Objects (KBOs) and on comets by reproducing the space environment in laboratory experiments. A study of these KBOs is important because they resemble natural ‘time capsules’ at a frozen stage before life developed on Earth. We follow the methodology that a comparison of the molecules formed in the experiments with the current composition of KBOs provides an exceptional potential to reconstruct the composition of icy, outer Solar System bodies at the time of their formation billions of years ago. Here, we present resent results of laboratory experiments simulating the interaction of ionizing radiation with low temperatures ices and mixtures relevant to the chemistry of KBOs and comets. Special attention is given to the reaction mechanisms on the synthesis of astrobiologically important molecules; amino acids, sugars, amines, carboxylic acids, and dipeptides

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315 – Multiple Populations in Globular Clusters: Dynamical Evolution

Meeting-in-a-Meeting – Room 3, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

This session focuses on understanding the dynamical evolution of the primordial and evolving objects that became today's globular clusters, as well as forthcoming approaches to tackle problems in this field.

315.01 – **Formation and Dynamical Evolution of Multiple Stellar Populations in Globular Clusters**

Enrico Vesperini[1]
[1]*Drexel Univ..*
2:00 PM - 2:30 PM

I will present the results of our studies exploring the formation and dynamical evolution of multiple stellar populations in globular clusters. The results presented will include a discussion of how the structural properties and the relative number of first- and second-generation stars evolve during a cluster early and long-term dynamical evolution.

I will also present results on the dependence of the amount of second-generation stars formed on a cluster initial properties.

The implications of the model presented for the fraction of globular cluster second-generation stars in the Galactic halo and, more in general, for the contribution of globular cluster stars to the Galactic halo assembly will be discussed.

Finally, I will present the results of a study showing the important role played by the presence of a second-generation star subsystem in the evolution and disruption of cluster first- and second-generation binary stars.

315.02 – **Modeling Self Enrichment and the Mass-Metallicity Relation**

Jeremy Bailin[1], B. Harris[2]
[1]*University of Michigan,* [2]*McMaster University, Canada.*
2:30 PM - 3:00 PM

We present a theoretical model to describe self-enrichment in globular clusters. Our model assumes that the highest mass stars formed, evolved, and exploded as supernovae while the lower-mass stars visible today were still forming, seeding the protocluster cloud with metals while also gravitationally unbinding some of the gas. A mass-metallicity relationship naturally arises in this model which, when combined with pre-enrichment of the protocluster cloud and dynamical evolution of the subsequent GC, provides a good match to the observed "blue tilt" of GCs around massive elliptical galaxies and predicts a milder "red tilt" at higher luminosities. I will also discuss possible explanations for the observed galaxy-to-galaxy variation of the blue tilt within this model.

315.03 – **Formation Processes Of Globular Clusters With Chemical Abundance Spread**

Kenji Bekki[1]
[1]*University of Western Australia, Australia.*
3:00 PM - 3:30 PM

We consider that the Galactic globular clusters were formed in the building blocks of the Galaxy (i.e., dwarfs) and thereby numerically investigate chemical abundances of the clusters. Our simulations show that massive and compact stellar clumps with masses larger than 10^6 M_{sun}, which can be regarded as progenitors of massive globular cluster (MGCs), can form from massive gas clumps that are developed through merging of gaseous regions initially at different radii and thus with different metallicities in the Galactic building blocks. Therefore it is inevitable that MGCs formed in dwarfs have heavy element abundance spread. The abundance spread in each individual MGC depends on the radial metallicity gradient of the host dwarf such that it can be larger for the steeper metallicity gradient. We discuss these results in the context of the origin of MGCs such as Omega Cen, M22, and NGC 2419. We also discuss the importance of globular cluster merging in understanding the origin of multiple stellar populations in globular clusters.

316 – Wide-Field IR Space Telescope Science: Dark Energy Science

Meeting-in-a-Meeting – Summit Hall 3, Egan Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

The Astro2010 Decadal Survey gave its highest recommendation in the large-scale space mission category to WFIRST, a Wide-Field Infrared Survey Telescope with both imaging and spectroscopy capabilities. The science made possible by such a facility reaches across many disciplines from dark energy to exoplanets to deep surveys. The dark energy measurements will be made using four principal measurement techniques: Baryonic Acoustic Oscillation (BAO), Redshift Space Distortions (RSD), Type 1a supernovae (SNe), and weak lensing (WL). Large area imaging and spectroscopic surveys will enable the BAO, RSD and WL techniques. Monitoring observations will enable the SNe technique. The dark energy science aspects of WFIRST will be discussed in this session.

316.01 – **Dark Energy, Particle Physics and Cosmology**

Michael S. Turner[1]

[1]*The University of Chicago.*

2:00 PM - 2:30 PM

Dark energy and cosmic acceleration is one of the three pillars of the current cosmological paradigm. Moreover, both raise fundamental issues in cosmology and particle physics. In particle physics, the dark energy problem is intimately related to the perplexing issue of why the quantum energy of the vacuum is so small. In cosmology, the nature of the dark energy is crucial to understanding the destiny of the Universe. I will discuss the status of current models for dark energy -- including vacuum energy and rolling scalar fields -- their implications for cosmology and for particle physics and how they can be tested by WFIRST. I will also address the status of the possibility that cosmic acceleration is explained by modifying or replacing general relativity.

316.02 – **Dark Energy: Systematics Requirements and Future Prospects**

Dragan Huterer[1]

[1]*University of Michigan.*

2:30 PM - 3:00 PM

We describe key physical quantities -- distance, growth of density fluctuations, and the expansion rate -- whose temporal evolution needs to be accurately mapped out in order to help understand the nature of dark energy. We show constraints on these quantities from current cosmological measurements, comment on the potential of upcoming and future data, and discuss the associated figures-of-merit. We then discuss key systematic errors that stand in the way of making such measurements. We review recent progress in understanding and parametrizing the systematics, and discuss future prospects and requirements.

316.03 – **Exoplanet Demographics with a Space-Based Microlensing Survey**

B. Scott Gaudi[1]

[1]*Ohio State Univ..*

3:00 PM - 3:30 PM

Measurements of the frequency of exoplanets over a broad range of planet and host star properties provide fundamental empirical constraints on theories of planet formation and evolution. Because of its unique sensitivity to low-mass, long-period, and free-floating planets, microlensing is an essential complement to our arsenal of planet detection methods. I motivate microlensing surveys for exoplanets, and in particular describe how they can be used to test the currently-favored paradigm for planet formation, as well as inform our understanding of the frequency and potential habitability of low-mass planets located in the habitable zones of their host stars. I explain why a space-based mission is necessary to realize the full potential of microlensing, and outline the expected returns of such surveys. When combined with the results from complementary surveys such as Kepler, a space-based microlensing survey will yield a nearly complete picture of the demographics of planetary systems throughout the Galaxy.

317 – Galaxy Mergers from the Largest to the Smallest Scales: Active SMBHs

Meeting-in-a-Meeting – Room 2, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

This session gives an overview of the key properties of accretion onto single SMBHs, and how they appear in observations; and sets the stage for modeling, and successful searches in observations, of accretion onto wide and compact pairs of SMBHs. The first part gives an overview of the physics of accretion activity and key observational signatures, while the second part addresses current and ongoing large-area surveys which will detect large numbers of single and binary AGN.

317.01 – **AGN Variability at Low Energies**

Erin Wells Bonning[1]

[1]*Yale University.*

2:00 PM - 2:20 PM

Accretion onto supermassive black holes is a fundamentally multiwavelength phenomenon with significant emission across the electromagnetic spectrum giving insight into the numerous processes driven by the central engine of an active galaxy. Variability at all wavelengths can probe dynamical processes at different spatial and energetic scales. I will focus on variability at low energies (radio to optical/UV) and discuss intermittancy in radio galaxies, long timescale quasi-periodic signals in AGN light curves, short term variability and relativistic jets. Evidence for and against binary black holes will be discussed as well as the AGN - X-ray binary connection at these wavelengths.

317.02 – **AGN Variability at X-ray Energies**

Lance Miller[1]

[1]*Oxford University, United Kingdom.*

2:20 PM - 2:40 PM

AGN are observed to vary on ks timescales at X-ray energies, implying that the high-energy emission regions are at most a few tens of gravitational radii in size. Variability studies therefore allow us to probe the structure of AGN to much higher spatial resolution than can otherwise be achieved. Variability powerspectra usually show a characteristic timescale that varies with the mass of the black hole and the accretion rate, but where the detailed shape of the powerspectrum is a function of photon energy. Time lags are measured between wavebands of differing X-ray photon energy: observers do not yet agree on the interpretation of these lags, but there is compelling evidence that they arise from reverberation caused by scattering of continuum X-ray photons from reprocessing material a few tens to hundreds of gravitational radii from the black hole. There appear to be two dominant mechanisms of variability: intrinsic variation of the emission and/or variations in absorption by intervening reprocessing material in the immediate environment of the black hole. These may operate on different timescales and have differing spectroscopic variability signatures. Spectroscopically, there is now strong evidence for variable reprocessing by inhomogenous, outflowing material, with a high global covering fraction. Both variability and spectroscopic signatures may arise as a turbulent wind from the accretion disk, and the expected spectra have recently been computed using 3D radiative transfer models.

317.03 – **Pan-STARRS1: Transient AGN Events and High Redshift Quasars**

Kenneth C. Chambers[1]

[1]*Univ. of Hawaii.*

2:40 PM - 3:00 PM

Pan-STARRS1 began the PS1 Science Mission May 13, 2009. Operations of the PS1 System include the Observatory, Telescope, 1.4 Gigapixel Camera, Image Processing Pipeline , PSPS relational database and reduced science product software servers. The PS1 Surveys are sensitive to black hole accretion events(e.g. flares from tidal disruption) by identification of a transient event and the detection of high redshift (z~7) and binary black holes through stacked images. PS1's advance is its time-domain coverage in multiple filters (grizy), and the near-infrared coverage in the y-band (1-micron). At least one tidal disrupton event has been caught while the light curve was still rising, and a faint $z=6.4$ quasar has been found. Early results in transient and static sky AGN science will be presented.

317.04 – **The Frequency and Demographics of Active Galactic Nucleus Pairs: from Tens-of-kpc to Sub-kpc Scales**

Xin Liu[1]

[1]*Harvard College Observatory.*

3:00 PM - 3:20 PM

Active Galactic Nucleus pairs are actively accreting massive black holes co-rotating in merging galaxies with separations of less than a few tens kpc. Despite decades of searching, and strong theoretical reasons to believe they exist, unambiguously confirmed AGN pairs remained surprisingly scarce. In the past few years, the combination of systematic searches, and in particular those using large optical spectroscopic surveys, with dedicated follow-up observations enabled statistically robust investigation of the frequency and demographics of AGN pairs down to separations of a few hundred pc. I will discuss results from these systematic searches, and will highlight our ongoing HST SNAP survey to explore AGN pairs at a more advanced merger stage - a largely uncharted regime - towards building a more coherent picture of the accretion and evolution of massive black hole pairs in mergers.

318 – Kepler's Future: the Road to Eta-Earth

Meeting-in-a-Meeting – Ballroom A, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

This session will present plans for the future of the Kepler Mission. The discussion will include the progress towards Kepler's goal of determining the frequency of terrestrial planets in the habitable zone of solar-like stars. Talks will cover the statistics of

exoplanets based on Kepler results, including discussion the false-positive rate and the completeness of the Kepler results. The session will cover plans for the future of Kepler, including data collection, processing, and archiving.

318.01 – **Kepler: Updated Exoplanet Statistics and an Estimate of the Frequency of Planetary Candidates in the Habitable Zone**

William J. Borucki[1]

[1]*NASA Ames Research Center.*

2:00 PM - 2:15 PM

Analysis of current Kepler observations show the presence of over 2300 candidate planets and more than 2200 eclipsing binary stars. The sizes of planetary candidates range from that of Mercury to over twice the size of Jupiter. Several dozen candidates are found in the habitable zone of the host stars. Circumbinary planets have been confirmed and several 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 multi-candidate systems is being used to determine planet masses and thus the density of the planets. 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 and provide a larger number of targets that can be processed successfully. Intrinsic distributions of the candidates based on six seasons of observations are 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.These results and a brief summary of Mission results are presented.

Funding for this Discovery Mission is provided by the NASA Science Mission Directorate.

318.02 – **The Occurrence of Planets 1-10x the Size of Earth**

Andrew W. Howard[1]

[1]*UC Berkeley.*

2:15 PM - 2:27 PM

The currently observed architectures of extrasolar planetary systems trace the processes of planetary formation and evolution. Until recently, Jovian-size planets provided nearly all of the observational constraints. With Kepler we see representatives of nearly all planets down to Earth size and out to 1 AU. My talk will focus on planet occurrence measurements as a function of planet size, orbital distance, and host star properties. Kepler has shown with much higher fidelity than previous surveys that small planets are the most abundant despite being the most difficult to detect. Analyses of the Kepler data support the bottom-up picture of planet formation by core accretion, but also raise new questions about the mechanisms of planet migration, the timing of protoplanetary gas depletion, and the effect of stellar mass on small planet formation.

318.03 – **Results From The Search For Planetary Companions To Kepler Hot Jupiter Candidates**

Jason H. Steffen[1], Kepler Science Team

[1]*Fermilab.*

2:27 PM - 2:39 PM

NASA's Kepler mission has identified a sizeable population of candidate hot Jupiter systems. Various planet formation theories make different predictions on the presence of additional planets in nearby, near-resonant orbits. I present the results of a search for these companion planets in hot Jupiter systems from the Kepler data. These results will help narrow the range of possible explanations for the existence of hot Jupiter planets and provide insight into the various types of planetary systems in our galaxy.

318.04 – **Validation And Characterization Of The Jupiter-sized Planets KOI-196 And KOI-217**

Elisa V. Quintana[1], J. Rowe[1], T. Barclay[2], Kepler Team

[1]*SETI Institute,* [2]*NASA Ames Research Center.*

2:39 PM - 2:51 PM

We present high precision photometry of two Kepler Object of Interests KOI-196 and KOI-217 that reveal giant planets in short-period orbits around faint stars. Each time series is fit to a transit model and we measure the occultation and phased light curve. To confirm the planetary nature of these objects, we simulate third light contamination scenarios which can mimic a planetary transit signal by injecting a full range of dilution values into the model. The resulting constraints on the maximum occultation depth and stellar density combined with stellar evolution models rules out stellar blends and provides a measurement of each planet's mass, size, and temperature.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by the NASA Science Mission Directorate.

318.05 – **A Waypoint on the Road to Eta$_{\mathrm{Earth}}$: Improving the Sensitivity of Kepler's Science Pipeline**

Jon Michael Jenkins[1]

[1]*SETI Institute/NASA Ames Research Center.*

2:51 PM - 3:03 PM

NASA's Kepler Mission has discovered a plethora of planetary systems in the three years that it has been operating and is delving deeper to uncover smaller and smaller planets in longer and cooler orbits. Our ultimate goal is to determine eta$_{\mathrm{Earth}}$, the frequency of terrestrial planets in the habitable zone (HZ) of solar-like stars in our galaxy. Kepler's ability to detect weak signatures of terrestrial planets in habitable orbital abodes is complicated by unexpectedly high stellar variability exhibited by main-sequence, solar-like stars (20 ppm rather than 10 ppm on timescales of 6.5 hours), and by transients in the data caused chiefly by thermal effects in the spacecraft and photometer, as well as occasional, radiation-induced sudden drops in pixel sensitivity. Kepler's observations need to be extended to ~8 years in order to recover the expected pre-launch sensitivity to HZ planets. Significant performance improvements in dealing with instrumental systematic effects have been obtained through Bayesian approaches, resulting in light curves that retain intrinsic astrophysical signatures as well as lower photometric noise. However, additional improvements are necessary in order to realize the full benefits of an extended mission. Other important tasks include characterizing the completeness and reliability of the detection pipeline, and minimizing the manual effort necessary to vet the planetary signatures it identifies. This talk summarizes the status of these activities, all of which are required to reach a robust estimate of eta$_{\mathrm{Earth}}$.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA's Science Mission Directorate.

318.06 – **The Kepler Completeness Study: Implications for Small Planets**

Jessie Christiansen[1], C. J. Burke[1], B. D. Clarke[1], Kepler Completeness Study Working Group

[1]*NASA Ames Research Center/SETI Institute.*

3:03 PM - 3:15 PM

The Kepler Science Office is undergoing a large study into the completeness of the sample of transiting planets, which is a critical step towards completing Kepler's primary mission goal of determining eta$_{\mathrm{Earth}}$. One of the initial efforts has been towards performing an internal pipeline calibration. We study this by injecting many thousands of simulated transits into the Kepler light curves at the start of the pipeline, and then examining the fidelity of those transits at the point in the pipeline where the transit search is performed. We present here some preliminary results, focussing on super-Earth-size planets and smaller. It is these planets, which are likely to have a lower completeness due to their lower signal-to-noise events, where constraining the completeness is vital for determining a precise value of eta$_{\mathrm{Earth}}$.

318.07 – **Eliminating False-Positives in the Kepler Planet Catalog**

Steve Bryson[1]

[1]*NASA Ames Research Center.*

3:15 PM - 3:27 PM

A primary goal of NASA's Kepler mission is the estimation of the frequency of exoplanets via the detection of planetary transits. Eliminating false-positives due primarily to diluted or grazing eclipsing binary stars is a critical component of such an estimate. This presentation will survey false-positive identification via analysis of Kepler pixels and light curves, as well as ground-based follow-up. We describe several methods we use to determine the location of a transit signal source from the Kepler pixels, and how the probability of a background false positive source is determined. Light curve analysis indicates whether the target star is itself an eclipsing binary. When ground-based spectra indicate that the target is a binary system that target is placed on a provisional false-positive list until it can be determined if the binary ephemeris is consistent with the observed transit. Ground-based high-resolution imaging is critical for the identification of background/foreground stars that may be the source of the transit. The results of these analyses are the Kepler false-positive table and a measure of confidence for the remaining Kepler planetary candidates. We will briefly survey the population of background binary stars detected by Kepler.

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319 – Novae, Pulsars, Neutron Stars, and GRBs

Oral Session – Ballroom C, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

319.01 – **O VI Recombination Lines In Ultraviolet And Visible Spectra Of Rr Telescopii**

Peter R. Young[1]

[1]*George Mason University.*

2:00 PM - 2:10 PM

Nineteen recombination lines of O VI are identified in ultraviolet and visible spectra of the symbiotic nova RR Telescopii at wavelengths between 1122 and 6203 A. Only three of the lines have previously been reported from astronomical spectra, and eight lines have never been reported from either astronomical or laboratory spectra. The lines represent transitions between levels with principal quantum numbers up to 13 and the strongest lines by flux occur at 1124.82, 2070.90 and 3434.66 A, corresponding to transitions 4-5, 5-6 and 6-7. As the lines are produced by recombination onto O VII they potentially allow O VII emitting regions in astrophysical plasmas to be probed at ultraviolet and visible wavelengths that otherwise can only be studied at X-ray wavelengths.

319.02 – **Nebular Remnants of Classical Novae Resolved with Keck Adaptive Optics**

Randall Campbell[1], J. Lyke[1], M. Kassis[1]

[1]*W.M. Keck Observatory.*

2:10 PM - 2:20 PM

The advent of large ground based telescopes equipped with adaptive optics has significantly improved the capability of studying the nebular remnants of Classical Novae , CN. The W. M. Keck Observatory's laser guide star adaptive optics, LGSAO, coupled with the integral field spectrometer OSIRIS and the near infrared camera NIRC2 are powerful tools for observing novae ejecta. With this state-of-the-art instrumentation, nova shells can now be resolved much sooner in the nebular phase while they are still bright and while they still preserve some of the characteristics embedded during the nova process. The study of CN ejecta can contribute to the understanding of the physical processes of the nova event, the properties of the underlying WD, the nebular shaping mechanisms, and CN as contributors to the interstellar medium. Furthermore, expansion parallax of the shell is an effective method for determining accurate distances to these objects, an important fundamental property. We present observational data for several recent novae and discuss the details of two distinct types of remnants; one type observed at high excitation nebular emission lines with OSIRIS and another observed at the thermal IR emission from dust formation using NIRC2. The method of determining distance to these objects will be presented as well as analysis techniques used with the IFS 3D data.

319.03 – **Modeling the Surface Emission and Viewing Geometry of PSR J0821-4300 in Puppis A**

Eric V. Gotthelf[1]

[1]*Columbia Astrophysics Lab..*

2:20 PM - 2:30 PM

We summarize our latest results on applying the antipodal emission model to the central compact object (CCO) in the supernova remnant Puppis A. This model assumes two opposing thermal hot spots on the surface of the neutron star (NS) and includes a spectral feature located to the cooler pole, whose flux may be variable in time. The antipodal is able to reproduce the unique observational properties of the pulsar, its overall spectral shape, energy-dependent pulsed modulation, and the abrupt 180 degree phase reversal at the crossover energy of the two fitted blackbody components. Using the latest phase-connected timing solution for PSR J0821-4300, based on 200 ks of XMM and Chandra observations spanning 2 years, we compare the energy dependent profile with the model predictions in sufficient detail to further constrain the antipodal model. We consider any time evolution of the spectrum, in particular, the spectral deviations from a pure blackbody evident on the cooler pole. We also present our latest measurement of the period derivative, accurate to 5%, that has likely reached the Shkloski limit for the high proper motion NS, whose spin-down rate is nearly imperceptible. With a timing estimate of the magnetic field of order 10^11 Gauss, the essential problem in understanding PSR J0821-4300 and the other CCO pulsars is how to reconcile their highly anisotropic emission without creating a strong external dipole magnetic field.

319.04 – **Imaging Pulsar Polar Caps with Scintillation Statistics**

Michael Johnson[1], C. R. Gwinn[1], P. Demorest[2]

[1]*Univ. California, Santa Barbara,* [2]*National Radio Astronomy Observatory.*

2:30 PM - 2:40 PM

Diffractive interstellar scintillation has long been used to image pulsars with remarkable resolution. The scattering material acts as an AU-scale stochastic lens, with a corresponding diffractive scale of thousands of kilometers. We present novel statistical techniques that describe the distribution of flux density, measured with Nyquist-limited resolution. These techniques resolve the emission structure at a few percent of the diffractive scale and can identify the emission structure of individual pulses. We analyze GBT observations of the Vela pulsar at 800 MHz, which yield a resolution of a few kilometers at the pulsar -- nearly the size of the polar cap. We discuss the implications for pulsar emission physics and the capabilities of future observations.

319.05 – **Resonant Shattering of Neutron Star Crusts**

David Tsang[1], J. S. Read[2], T. Hinderer[3], A. Piro[1]

[1]*California Institute of Technlogy,* [2]*University of Mississippi,* [3]*University of Maryland.*

2:40 PM - 2:50 PM

The resonant excitation of neutron star (NS) modes by tides is investigated as a source of short gamma-ray burst (SGRB) precursors. We find that the driving of a crust-core interface mode can lead to shattering of the NS crust, liberating ~10^46-10^47[[Unsupported Character -]][[Unsupported Character -]]erg of energy seconds before the merger of a NS-NS or NS-black-hole binary. Such properties are consistent with Swift/BAT detections of SGRB precursors, and we use the timing of the observed precursors to place weak constraints on the crust equation of state. We describe how a larger sample of precursor detections could be used alongside coincident gravitational wave detections of the inspiral by Advanced LIGO class detectors to probe the NS structure. These two types of observations nicely complement one another, since the former constrains the equation of state and structure near the crust-core boundary, while the latter is more sensitive to the core equation of state.

319.06 – **The Intrinsic Nature Of A Luminosity- Time Correlation In The X-ray Afterglows Of Grbs**

Maria Dainotti[1], V. Petrosian[1], J. Singal[1]

[1]*Stanford University.*

2:50 PM - 3:00 PM

Gamma -ray bursts (GRBs) observed up to redshifts z>9.3 are fascinating objects to study due to their still unexplained relativistic outburst mechanisms and a possible probes of the early universe. Our analysis of a new and larger (100) sample of GRB afterglows with known redshifts and definite plateau confirms the correlation found earlier (Dainotti 2010) between the break time at the end of plateau T_a and the plateau luminosity L*_X(T_a) (called hereafter L^*_a) with a higher value of the Spearman correlation coefficient. Here we present a new test of the sample using the non-parametric method of Efron & Petrosian (1992) to determine the intrinsic correlation corrected for possible correlation induced due to large redshift range of the sample. In addition with this method we determine the redshift evolution in both the luminosity and time T_a. This test shows that the observed correlation is not redshift induced but it is intrinsic. The novelty of this approach is that the Efron & Petrosian method has been applied for the first time to a two parameters correlation that involves not only luminosities, but also time. Even though this correlation is not sufficiently tight to allow us to determine the distance for given T_a Flux, and spectral index, nevertheless it can be useful to constrain physical models for the plateau emission.

319.07 – **Photospheric Emission As The Dominant Radiation Mechanism In Long-Duration Gamma-Ray Bursts**

Brian J. Morsony[1], D. Lazzati[2], M. C. Begelman[3]

[1]*University of Wisconsin-Madison,* [2]*North Carolina State University,* [3]*University of Colorado, Boulder.*

3:00 PM - 3:10 PM

We present new simulations of GRB photospheric emission that are able to quantitatively reproduce important observational correlations.

Two key observational constraints on GRB emission are that the more energetic events are characterized by photons of higher frequency (Amati et al. 2002) and they are produced by outflows with higher velocity (Liang et al. 2012, Ghirlanda et al. 2012). Earlier work indicated that photospheric emission can qualitatively account for the former constraint but is unable to quantitatively reproduce the photon frequency of a burst of given energy. Simulated bursts were found to be softer than their observed counterparts. Here we report simulations that produce both the observed relations. The key physics not previously captured is that the photospheric spectrum is formed at the surface of last energy exchange between the radiation and the electrons rather than at the surface of last scattering (Giannios 2011). We find that simulated GRBs are relatively insensitive to the details of the progenitor star and injected jet. However, their characteristics are strongly dependent on the angle between the jet axis and the line of sight to the observer. This implies that the observed correlations are mainly due to the polar stratification of the outflow induced by its interaction with the progenitor star. We also find that the radiative efficiency of simulated bursts is correlated to the burst energetics, a prediction that can potentially be tested against observations.

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320 – AGN, QSO, Blazars I

Oral Session – Room 1, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

320.01 – **Broad Absorption Line Variability on Multi-Year Timescales: Current Results and SDSS-III Prospects**

W. Niel Brandt[1], N. Filiz Ak[1], P. B. Hall[2], D. P. Schneider[1], BOSS Quasar Working Group

[1]*Penn State Univ.,* [2]*York Univ., Canada.*

2:00 PM - 2:10 PM

Over the past few years, studies of the variability of quasar Broad Absorption Lines (BALs) on multi-year rest-frame timescales have provided a number of intriguing results. These include (1) quantification of how BAL variability increases with rest-frame timescale, (2) characterization of the basic modes of multi-year BAL variability; e.g., variation often occurs in discrete regions which are only a few thousand km/s wide, and (3) tight limits upon BAL acceleration enabled by the long sampled timescales. We are aiming to transform the field of multi-year BAL variability studies into one that supplies rigorous large-sample constraints upon quasar winds using an ancillary project of the SDSS-III Baryon Oscillation Spectroscopic Survey (BOSS). BOSS is re-observing 2000 bright BAL quasars originally observed by SDSS-I/SDSS-II from 2000-2008. This sample size is ~ 100 times larger than those of current multi-year BAL variability studies, and > 800 objects are already observed. Measured variations constrain, e.g., BAL disappearance and emergence, BAL lifetimes, the modes of multi-year BAL variability, and BAL acceleration. For example, we have already detected about 20 new examples of BAL disappearance events. Soon we will constrain the dependence of multi-year BAL variability upon luminosity, redshift, black-hole mass, Eddington fraction, and radio properties.

320.02 – **The Long-term X-ray Variability Of Broad Absorption Line Quasars**

Cristian Saez[1], N. Brandt[1], S. Gallagher[2], F. Bauer[3], G. Garmire[1]

[1]*The Pennsylvania State University,* [2]*The University of Western Ontario, Canada,* [3]*Pontificia Universidad Catolica de Chile, Chile.*

2:10 PM - 2:20 PM

We analyze X-ray the variability of eleven broad absorption line (BAL) quasars. This sample has coverage with multiple X-ray observations including Chandra, XMM-Newton , BeppoSAX , ASCA, ROSAT , and Einstein. In seven out of the eleven sources we have analyzed new short Chandra observations (5-7 ks) suitable for searching for any strong X-ray variability. Our X-ray coverage on each source spans approximately six X-ray observations with a rest-frame time of 13.7 years. We find evidence of X-ray variability (with significance >99%) in three sources (PG 1001+054, PG 1004+130, and PG 2112+059). The flux amplitude of the variability is 3.3 ± 1.2, 1.50 ± 0.06, and 10.8 ± 2.6 with rest-frame times scales of approximately 5.8, 1.4, and 0.5 years for PG 1001+054, PG 1004+130, and PG 2112+059 respectively. For PG 1004+130 and PG 2112+059 we also find significant (with significance >99%) spectral X-ray variability associated to their flux variability. Additionally, we report for the first time an X-ray detection of IRAS 14026+4341 with statistical significance of ≈5σ in its new Chandra observation.

320.03 – **Extreme Velocity Quasar Outflows and the Role of X-Ray Shielding**

Frederick W. Hamann[1], P. Rodriguez Hidalgo[2], G. Chartas[3], S. Joseph[4], J. Charlton[5], M. Eracleous[5]

[1]University of Florida, [2]University of Toronto, Canada, [3]College of Charleston, [4]Ohio University, [5]Pennsylvania State University.

2:20 PM - 2:30 PM

High velocity outflows are ubiquitous in quasars and possibly important for feedback to galaxy evolution. X-ray studies have shown that outflows with broad absorption lines (BALs) in the rest-frame UV also have strong X-ray absorption, but flows with only narrower "mini-BALs" are dramatically less X-ray absorbed. This disparity raises serious doubts about a key theoretical premise: that strong X-ray/far-UV shielding is needed to drive these flows radiatively to high speeds. We obtained Chandra ACIS-S spectra of 7 quasars that are approximately matched to previous samples in luminosity and mini-BAL strength, but with much higher outflow velocities that now double the range covered by previous work. These data overall will place new strong constraints on the acceleration physics and the role of radiative shielding. Preliminary analysis suggests that the extreme high-velocity outflow sources do not have stronger x-ray absorption than low-speed outflow sources, and therefore, apparently, strong radiative shielding is not needed for the acceleration to high speeds. A full report will be presented.

320.04 – **Extremely High Velocity Outflows in Quasars**

Paola Rodriguez Hidalgo[1], P. Hall[1], J. Charlton[2], G. Chartas[3], F. Hamann[4], M. Eracleous[2], J. Shields[5]

[1]York University, Canada, [2]Penn State University, [3]College of Charleston, [4]University of Florida, [5]Ohio University.

2:30 PM - 2:40 PM

Outflows in Active Galactic Nuclei (AGN) bring information about the physical and chemical properties of the AGN inner environments. Moreover, they are fundamental constituents of AGN: they might be ubiquitous, they might connect the Super-Massive Black Hole (SMBH) environment with the host galaxy via ''feedback'', and they might play a role in blowing out the gas and dust from young galaxies and distributing metal-rich gas to the intergalactic medium. Of special interest are the cases with extremely large velocities (v > 0.1c) because they present the biggest challenge to theoretical models and can help constrain the acceleration mechanisms proposed to be driving these outflows.

Despite our progress in understanding their characteristics and their frequency, the geometry and the physics of the outflow phenomenon in active galactic nuclei remains unknown. I will report on the progress of a multi-wavelength campaign, which aims to characterize the chemical and physical properties of some of the fastest UV/optical outflows found in quasars.

320.05 – **How Much Do X-ray Warm Absorbers, In AGN, Care About The UV Continuum?**

Susmita Chakravorty[1], J. C. Lee[1], G. A. Kriss[2]

[1]Harvard University, [2]Space Telescope Science Institute.

2:40 PM - 2:50 PM

Observations of AGN show signatures of outflowing gas which, in mass-energy budget, is often a significant fraction of the matter that is being accreted. The ionizing continuum seen by these absorption systems spans the entire energy range from the UV to the X-rays. Inspite of this, the properties of the absorbing gas seen in the UV are derived in isolation from the derivation of the properties of the X-ray absorbing warm gas. We shall demonstrate in this presentation that this `isolated traditional approach' may be inadequate and may lead to incorrect predictions for (a) the `colocation' of the UV and X-ray absorbers and (b) the structure and geometry of the absorbing system. As such we shall emphasise the importance of a consistent UV to X-ray treatment of AGN observations.

320.06 – **The Relationship between Feedback Rates and Supermassive Black Hole Spin Evolution**

Ruth A. Daly[1]

[1]Penn State Univ..

2:50 PM - 3:00 PM

The redshift evolution of spins for a large sample of supermassive black holes will be presented. The supermassive black holes studied are associated with large-scale radio sources and have redshifts between about zero and two. The relationship between evolution of black hole spin and the rate of energy input to the ambient gas by large-scale outflows from AGN will be derived and discussed. These theoretical results will be compared with empirical results to quantify and study the relationship between black hole spin evolution and the rate of energy input to the environments of AGN.

320.07 – **Probing the Nature of Low Luminosity AGN via Megamaser Activity**

Anca Constantin[1]

[1]James Madison University.

3:00 PM - 3:10 PM

Megamaser disks allow for accurate determination of supermassive black hole masses and for cosmic distance determination of extremely high precision. There is some evidence that mega-maser activity is related to black hole accretion, however, we are curently lacking a good understanding of the special physical characteristics that facilitate the maser production in galaxy centers. This contribution presents the results of a novel multi-parameter comparative investigation of the optical host and nuclear properties of galaxies with and without water maser emission, separated in spectral classes that correlate with the strength and type of nuclear galactic activity. This analysis suggests that mega-maser disk activity is related to a "goldilocks" parameter range that might correspond to a particular phase in an evolutionary sequence in which galaxies transform from star-forming via AGN to quiescence. These findings are likely to boost the megamaser disk detection rate to 25% among newly surveyed galaxies.

320.08 – **The Radio and Optical Luminosity Evolution of Quasars: AGN Were More Radio Loud In The Past**

Jack Singal[1], V. Petrosian[1]

[1]KIPAC - Stanford.

3:10 PM - 3:20 PM

We present a new determination of the radio and optical luminosity evolution with redshift of quasars from data that is flux-limited in both bands. The methods employed are non-parametric and can deal with the detection selection biases to determine the intrinsic distributions directly from the observational data. Using data from several sources including the SDSS Data Release 7 quasar catalog, we show that as a population quasars were more radio loud at earlier epochs, with implications for the evolving physics of AGN and the contribution of quasars as a source class to the cosmic radio background radiation. Quantifying the differential evolutions allows a reconstruction of the intrinsic distribution of radio loudness as a function of redshift, and the reconstructed intrinsic distribution differs markedly from the observed one, in particular favoring the conclusion that quasars form a continuum rather than distinct radio loud and radio quiet sub-populations.

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321 – Dark Matter, Dark Energy, and Large Scale Structure

Oral Session – Ballroom B, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

321.01 – **Mapping the Dark Matter with 6dFGS**

Jeremy R. Mould[1], C. Magoulas[2], C. Springob[3], M. Colless[3], H. Jones[4], J. Lucey[5], P. Erdogdu[6], L. Campbell[7]

[1]Swinburne University, Australia, [2]Melbourne University, Australia, [3]AAO, Australia, [4]Monash University, Australia, [5]Durham University, United Kingdom, [6]UCL, United Kingdom, [7]WKU.

2:00 PM - 2:10 PM

Fundamental plane distances from the 6dF Galaxy Redshift Survey are fitted to a model of the density field within 200/h Mpc. Likelihood is maximized for a single value of the local galaxy density, as expected in linear theory for the relation between overdensity and peculiar velocity. The dipole of the inferred southern hemisphere early type galaxy peculiar velocities is calculated within 150/h Mpc, before and after correction for the individual galaxy velocities predicted by the model. The former agrees with that obtained by other peculiar velocity studies (e.g. SFI++). The latter is only of order 150 km/sec and consistent with the expectations of the standard cosmological model and recent forecasts of the cosmic mach number, which show linearly declining bulk flow with increasing scale.

321.02 – **Refined Dark Matter Determinations from Chandra Observations of Quadruply Lensed Quasars**

David A. Pooley[1]

[1]Eureka Scientific.

2:10 PM - 2:20 PM

We present a microlensing analysis of *Chandra* observations of 14 quadruply lensed quasars. X-ray flux measurements of the individual quasar images give a clean determination of the microlensing effects in the lensing galaxy and thus offer a direct assessment of the local fraction of stellar matter making up the total integrated mass along the lines of sight through the lensing galaxy. A Bayesian analysis of the ensemble of lensing galaxies gives a most likely local stellar fraction of 7%, with the other 93% in a smooth, dark matter component, at a mean impact parameter R_c of 6.6 kpc from the center of the lensing galaxy. We divide the systems into smaller ensembles based on R_c and find that the most likely local stellar fraction varies qualitatively and quantitatively as expected, decreasing as a function of R_c.

We gratefully acknowledge support from Chandra grant GO1-12135X.

321.03 – **Cmb Bounds On Dark Matter Properties**

Aravind Natarajan[1]

[1]*Carnegie Mellon University.*
2:20 PM - 2:30 PM

I discuss how precision measurements of the cosmic microwave background can place bounds on dark matter properties. I show that an accurate measurement of the CMB large angle polarization by the upcoming Planck satellite will significantly improve these bounds.

321.05 – **The Flight Path of Nearby Galaxies**

Edward J. Shaya[1]

[1]*Univ. of Maryland.*
2:40 PM - 2:50 PM

The Numerical Action Method can be used to calculate the flight paths of galaxies from the end of the linear regime well into the non-linear regime. A search for self consistent mutual gravitating orbits constrained by present positions and velocities results in solutions, sometimes multiple, of the history of formation of groups, sheets and superclusters, but not clusters. This includes obtaining total baryon plus dark matter masses. I will show results for the Local Group, The Virgo Supercluster, and the Hydra/Centaurus Supercluster.

321.06 – **Fundamental Constant Constraints on New Physics and Quintessence Models**

Rodger I. Thompson[1]

[1]*Univ. of Arizona.*
2:50 PM - 3:00 PM

Changes in the values of the fundamental constants mu, the proton to electron mass ratio, and alpha, the fine structure constant due to rolling scalar fields have been discussed both in the context of cosmology and in new physics such as Super Symmetry (SUSY) models. This article examines the changes in these fundamental constants in a particular example of such fields, freezing and thawing slow roll quintessence. Constraints are placed on the product of a cosmological quantity, w, the equation of state parameter, and the square of the coupling constants for mu and alpha with the field, $zeta_x$, x = mu, alpha using the existing observational limits on the values of (Delta x)/x. Various examples of slow rolling quintessence models are used to further quantify the constraints. Some of the examples appear to be rejected by the existing data which strongly suggests that conformation to the values of the fundamental constants in the early universe is a standard test that should be applied to any cosmological model or suggested new physics.

321.07 – **Acceleration of Black Hole Universe**

Tianxi Zhang[1]

[1]*Alabama A&M University.*
3:00 PM - 3:10 PM

An alternative cosmological model called black hole universe has been recently proposed by the author. According to this model, the universe originated from a hot star-like black hole, and gradually grew up through a supermassive black hole to the present state by accreting ambient materials and merging with other black holes. The entire space is structured with an infinite number of layers hierarchically. The innermost three layers are the universe that we live, the outside space called mother universe, and the inside star-like and supermassive black holes called child universes. The outermost layer has an infinite radius and limits to zero for both the mass density and absolute temperature. All layers or universes are governed by the same physics, the Einstein general theory of relativity with the Robertson-Walker metric of space-time, and tend to expand outward physically. The evolution of the space structure is iterative. When one universe expands out, a new similar universe grows up from its inside. In this study. we will analyze the acceleration of black hole universe that accretes its ambient matter in an increasing rate. We will also compare the result obtained from the black hole universe model with the measurement of type Ia supernova and the result from the big bang cosmology.

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322 – Solar Dynamics Observatory II

Oral Session – Room 5, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

322.01 – **Flare Half-Loops: What Are They?**

David Eugene McKenzie[1], S. E. Guidoni[1], D. W. Longcope[1], K. Yoshimura[1]

[1]*Montana State Univ..*
2:00 PM - 2:15 PM

The M1.4 flare of 28 January 2011 has a remarkable resemblance to the famous "Tsuneta candle-flame" flare of 1992. It was observed with Hinode/XRT, SDO/AIA, and STEREO (A)/EUVI, resulting in higher resolution, greater temperature coverage, and stereoscopic views of this iconic structure. The high temperature images reveal a brightening that grows in size to form a tower-like structure at the top of the arcade. They also show that loops which are successively connected to this tower develop a density increase in one of their legs that can exceed twice the density of the other leg, giving the appearance of "half loops". These jumps in density last for an extended period of time. On the other hand, XRT filter ratios suggest that temperature is approximately uniform along the entire loop. XRT filter-ratio density maps corroborate that the brighter legs have higher density than the fainter halves. The tower is associated with a localized density increase, with even higher densities than either leg of the loop. This spatial variation of density may correspond to a shock at the top of the loops. We use STEREO images to show that the half loop brightening is not a line-of-sight projection effect of the type suggested by Forbes & Acton. This work is supported under contract SP02H3901R from Lockheed-Martin to MSU, and under contract NNM07AB07C with the Harvard-Smithsonian Astrophysical Observatory.

322.02 – **Dynamical Heating In Flares Observed With SDO/AIA & RHESSI**

Iain Hannah[1], L. Fletcher[1], E. P. Kontar[1]

[1]*University of Glasgow, United Kingdom.*
2:15 PM - 2:30 PM

The spatial and temporal resolution of SDO/AIA data presents an unprecedented view of the dynamics of heating during solar flares. This combined with the non-thermal energetics from RHESSI hard X-ray imaging and spectroscopy provides constraints on the flaring energy release. The recently implemented regularized inversion method (Hannah & Kontar A&A 2012) robustly recovers the underlying thermal distribution (the Differential Emission Measure, DEM) of the coronal plasma from SDO/AIA images. Crucially it is not limited to the isothermal or Gaussian-model approximation that some other approaches depend upon. Our method provides the uncertainties in the DEM and is computationally quick, producing DEMs per pixel for a series of SDO/AIA images allowing temperature maps and movies to be created. We use the regularized inversion method to study the temporal and spatial evolution of the plasma heating in flares and show how the non-thermal energy relates to this. We also investigate how the calibration errors/uncertainties affect the inferred DEMs and errors.

322.03 – **Observation & Modeling of An Erupting Double-Decker Filament**

Rui Liu[1], B. Kliem[2], T. Toeroek[3], C. Liu[4], V. S. Titov[3], R. Lionello[3], J. A. Linker[3], H. Wang[4]

[1]*University of Science and Technology of China, China,* [2]*Institute of Physics and Astronomy, Germany,* [3]*Predictive Science, Inc.,* [4]*New Jersey Institute of Technology.*
2:30 PM - 2:45 PM

We study an active-region dextral filament which was composed of two branches separated in height by about 13 Mm. This ``double-decker'' configuration sustained for days before the upper branch erupted on 2010 August 7. Main results are as follows. 1) During hours before the eruption, filament threads within the lower branch were observed to intermittently brighten up, lift upward, and then merge with the upper branch. The merging process contributed magnetic flux to the upper branch, resulting in its quasi-static ascent. 2) This flux transfer might serve as the key mechanism for the upper branch to lose equilibrium by reaching the limiting flux that can be stably held down by the overlying field or by reaching the threshold of the torus instability. 3) The erupting branch first straightened from a reverse S shape that followed the polarity inversion line and then writhed into a forward S shape. This shows a transfer of left-handed helicity in a sequence of writhe-twist-writhe. The fact that the initial writhe is converted into the twist of the flux rope excludes the helical kink instability as the trigger process of the eruption, but allows for a role of the instability in the main phase. 4) A hard X-ray sigmoid, likely of coronal origin, formed in the gap between the two original filament branches in the impulsive phase of the associated flare. This supports a model of transient sigmoids forming in the vertical flare current sheet. 5) Using MHD modeling, we demonstrate that a configuration with two force-free flux ropes of like handedness can form in the slow-rise phase before an eruption and that it admits stable equilibria as well as the instability of only the upper rope.

322.04 – **Impulsively Driven Waves And Flows In Coronal Active Regions**

Leon Ofman[1], T. Wang[1], J. M. Davila[2], W. Liu[3]

[1]*Catholic University and NASA's GSFC,* [2]*NASA's GSFC,* [3]*Stanford University and Lockheed Martin Solar and Astrophysics Laboratory.*
2:45 PM - 3:00 PM

Recent SDO/AIA and Hinode EIS observations indicate that both (super) fast and slow magnetosonic waves are present in active region (AR) magnetic structures. Evidence for fast (100-300 km/s) impulsive flows is found in spectroscopic and imaging observations of AR loops. The super-fast waves were observed in magnetic funnels of ARs. The observations suggest that waves and flow are produced by impulsive events, such as (micro) flares. We have performed three-dimensional magnetohydrodynamic (3D MHD) simulations of impulsively generated flows and waves in coronal loops of a model bi-polar active region (AR). The model AR is initiated with a dipole magnetic field and gravitationally stratified density, with impulsively driven flow at the coronal base of the AR in localized magnetic field structures. We model the excitation of the flows in hot (6MK) and cold (1MK) active region plasma, and find slow and fast magnetosonic waves produced by these events. We also find that high-density (compared to surrounding corona) loops are produced as a result of the upflows. We investigate the parametric dependence between the properties of the impulsive flows and the waves. The results of the 3D MHD modeling study supports the conjecture that slow magnetosonic waves are often produced by impulsive upflows along the magnetic field, and fast magnetosonic waves can result from impulsive transverse field line perturbations associated with reconnection events. The waves and flows can be used for diagnostic of AR structure and dynamics.

322.05 – **SDO / AIA Observations of Slow Mode Waves in Coronal Fan Loops**

Vadim Uritsky[1], J. M. Davila[1], N. M. Viall[2]

[1]*CUA at NASA/GSFC,* [2]*ORAU at NASA/GSFC.*

3:00 PM - 3:15 PM

We investigate slow mode waves in fan coronal loops observed by the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory spacecraft (~12 sec cadence, 0.6 arcsec pixels). The warm fan structure studied here was located at the periphery of quiescent active region NOAA AR 11082. A specialized software package has been developed for extracting subvisual modulations of SDO AIA intensity propagating along dynamic loop segments changing their shape and position during the observation. The processing steps include manual tracking of the segment location in time sequences of co-aligned multispectral AIA images, extracting wave-carrying filamentary segments from the surrounding background, constructing position - time diagrams representing temporal evolution of optical brightness along the filaments, and analysis of the obtained wave signatures. The results reveal a persistent wave activity in many fan loop segments characterized by a well-defined frequency and phase speed, with the best signal-to-noise ratio in 171Å and 193Å channels. For some filamentary segments, the wave parameters remained almost constant over the entire observing interval (~ 6 hours). The wave parameters varied across the studied structures. The fastest wave fronts exhibited strictly outward propagation while the slower waves could travel both inward and outward. The estimated phase velocity (80-100 km/s) and period (3-4 min) of the most stable outward wave mode are in a good agreement with earlier SOHO EIT and TRACE observations of slow magnetosonic waves in fan loops. The newly observed features include (1) the remarkable coherency of the wave pattern over a course of several hours, and (2) the detailed wave form of the process enabling quantitative analysis of nonlinear propagation and damping effects. No consistent dependence of the wave speed on the distance from the hot core region of AR 11082 was identified, which challenges the traditional picture of traveling magnetoacoustic oscillations in fan loops.

322.06 – **A Portrait of the Magnetic Sun: Observation and Modeling at Global and Active Region Scales**

Xudong Sun[1], T. Hoeksema[1], Y. Liu[1], X. Zhao[1], K. Hayashi[1]

[1]*Stanford University.*

3:15 PM - 3:30 PM

The solar magnetic field contains a vast amount of energy that powers the dynamic atmosphere. On the large scale, the dipole-like field waxes and wanes, reversing polarity in each activity cycle. Its strength and evolution history strongly modulate solar wind speed, heliospheric open flux, and their sources. On the smaller scale, active regions with non-potential kilogauss field often exhibit explosive behaviors that directly affect space weather conditions. Thanks to space-borne observatories such as MDI and HMI, it is possible to monitor the photospheric field constantly. The ability to diagnose the coronal field is also improving due to the advances of extrapolation models. This dissertation talk briefly summarizes the large scale magnetic field and solar wind structures of Cycle 23 based on the MDI data archive and potential field models. I then focus on a recent major active region observed by HMI. The vector magnetogram sequence, complemented by a non-linear force-free field extrapolation, portrays in detail the 3D current and energy evolution leading to major eruptions with good spatial and temporal resolution. Future work will include better constrained coronal field modeling and more accurate estimation of the energy, as well as the coupling between the small and large scale fields.

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323 – Solar Information Processing and Distribution in the Petabyte Era

Special Session – Room 4, Dena'ina Center – 6/12/2012 2:00:00 PM to 6/12/2012 3:30:00 PM

The data volumes and rates of SDO and ATST surpass anything previousin solar physics by almost two orders of magnitude. This session willhighlight the recent solutions that the solar physics community hasdevised for the distribution, retrieval, and automated analysis of thisdeluge of images.

There will be invited presentations on the following subjects:1) The Virtual Solar Observatory's central role in finding andretrieving on-line solar data, and the distribution of SDO data,

2) The automated feature recognition modules that have been developedby the Feature Finding Team to monitor and analyze the SDO data streamin near-real-time, creating a complete and consistent set of metadata(called catalogs in the past), thereby enabling scientific researchprojects that were not possible before,

3) The functionality and framework that the Heliophysics EventKnowledgebase (HEK) has created for accessing, sorting, and retrievingsolar metadata in a versatile and effective manner will be presented,

4) This will be complemented by a presentation on Helioviewer, a newlydeveloped means of rapidly accessing and viewing solar images on-linebased on JPEG2000 and the Google Earth tiling technique,

5) The ATST will come to surpass SDO in data volume, and the plannedapproaches for the distribution and analysis of these complicated datasets will be presented.

A parallel poster session will feature booths from various groups withhands-on educational demonstrations of the various new informationdelivery and processing software solutions that have been developed.In addition there will be traditional posters on the subject of this session.

323.01 – **The Helioviewer Project: Making Petabytes of Images Available to Everyone**

Jack Ireland[1], V. K. Hughitt[1], D. Mueller[2]

[1]*ADNET Systems, NASA's GSFC,* [2]*ESA/ESTEC, Netherlands.*

2:00 PM - 2:18 PM

The aim of the Helioviewer Project (supported by ESA and NASA) is to design services and clients which give users everywhere the capability to browse and visualize the behavior of the Sun and inner heliosphere and to give access to the underlying science data. Helioviewer Project services and clients allow users to explore archives of JPEG2000 files and easily create movies of heliospheric events at arbitrary times, locations, time-scales and length-scales, using

images from multiple instruments, overlaid using the FITS header information from the original science data. Images from early 1996 to the present day are currently available.

This presentation will begin with a short summary of the JPEG2000 standard, which is used to store a wavelet-compressed version of the original science image data and a full copy of the FITS header. This reduces storage requirements server-side when compared to the original science data, but also keeps important meta-data available for use by browse clients. The JPEG2000 standard also includes the JPEG2000 Internet Protocol (JPIP), which allows browse clients to efficiently stream images and dynamically assembled movies over the web by sending only the wavelet coefficients required to show the desired portion of the movie. These features enable efficient access to large archives of large images, such those created by the Advanced Imaging Assembly.

Current use of Helioviewer Project services and clients will be discussed. Plans for including images from other solar and heliospheric data-sets will also be discussed. Finally, I will outline the future integration of Helioviewer Project visualization capabilities with the data provision services of the Virtual Solar Observatory (VSO) and the solar phenomena catalog services of the Heliophysics Event Knowledgebase (HEK), to create more scientifically useful and integrated data search, browse and acquisition tools.

323.02 – **Image Recognition and Feature Detection in Solar Physics**

Petrus C. Martens[1]

[1]*Montana State University.*

2:18 PM - 2:36 PM

The Solar Dynamics Observatory (SDO) data repository will dwarf the archives of all previous solar physics missions put together. NASA recognized early on that the traditional methods of analyzing the data -- solar scientists and grad students in particular analyzing the images by hand -- would simply not work and tasked our Feature Finding Team (FFT) with developing automated feature recognition modules for solar events and phenomena likely to be observed by SDO. Having these metadata available on-line will enable solar scientist to conduct statistical studies involving large sets of events that would be impossible now with traditional means.

We have followed a two-track approach in our project: we have been developing some existing task-specific solar feature finding modules to be "pipe-line" ready for the stream of SDO data, plus we are designing a few new modules. Secondly, we took it upon us to develop an entirely new "trainable" module that would be capable of identifying different types of solar phenomena starting from a limited number of user-provided examples. Both approaches are now reaching fruition, and I will show examples and movies with results from several of our feature finding modules.

In the second part of my presentation I will focus on our “trainable” module, which is the most innovative in character. First, there is the strong similarity between solar and medical X-ray images with regard to their texture, which has allowed us to apply some advances made in medical image recognition. Second, we have found that there is a strong similarity between the way our trainable module works and the way our brain recognizes images. The brain can quickly recognize similar images from key characteristics, just as our code does. We conclude from that that our approach represents the beginning of a more human-like procedure for computer image recognition.

323.03 – **SDO data distribution and access with VSO**

Alisdair R. Davey[1], Virtual Solar Observatory Team

[1]*SAO.*

2:36 PM - 2:54 PM

The Virtual Solar Observatory's (VSO's) traditional role has been to enable interfaces that allow solar physicists to search for and download data sets of interest. VSO originally acted as a facilitator between scientists and the data providers, but with the Solar Dynamics Observatory (SDO), it has become a data distributor to improve access to the AIA and HMI data.

We describe the network of 'caching nodes' in the US, Europe and Korea that enable faster and more robust access to this data, and the flexibility of the distribution tools to enable the caching nodes to mirror specific data to match their

specific research interests, such as specific wavelengths of AIA data or products of HMI data.

VSO has strengthened its integration with IDL, providing new options for scientists to search, filter and download SDO data without leaving the standard solar analysis environment. Of particular relevance for SDO is the ability to specify a specific caching node to download data from; in combination with the VSO/SDO data distribution network, this provides users with faster access to AIA and HMI data.

We also describe our collaborations with Helioviewer, the Heliophysics Event Knowledgebase and SunPy to provide integrated tools to reduce scientists' time spent looking for and retrieving solar data.

323.04 – **Enabling systematic Heliophysics research with the Heliophysics Events Knowledgebase**

Neal E. Hurlburt[1]

[1]*Lockheed Martin Corp..*

2:54 PM - 3:12 PM

Understanding the heliophysical systems involved in space weather requires tools for conducting surveys of data and metadata to discern trends, correlations and causation. Virtual Observatories, data systems using web services and event-based systems such as the Heliophysics Events Knowledgebase (HEK) and Heliophysics Integrated Observatory (HELIO), makes it possible to carryout integrated studies that span the full range of Heliophysics. I present recent developments of the HEK that aid such studies and discuss future plans.

323.05 – **ATST Data Distribution and Analysis**

Kevin P. Reardon[1]

[1]*National Solar Observatory.*

3:12 PM - 3:30 PM

The Advanced Technology Solar Telescope will be a key research facility for solar physics in the coming decade. ATST will produce large volumes of data covering the full solar atmosphere. The objective is to turn this stream of images and spectra into well-calibrated data products useful for the broad solar physics community. Some of the data processing challenges include managing the tens of terabytes of data that can be produced on a daily basis, the correction of distortions produced by the terrestrial atmosphere, and the extraction of physical parameters from the high-resolution observations. We will describe the approaches we will take in addressing these issues, as well as the ways in which the ATST data can be integrated with other data resources and made available through the VSO.

324 – Measuring Cosmic Rays at 1 PeV and Above

Invited Session – Ballroom B, Dena'ina Center – 6/12/2012 3:40:00 PM to 6/12/2012 4:30:00 PM

324.01 – **Measuring Cosmic Rays at 1 PeV and Above**

Katherine Rawlins[1]

[1]*University of Alaska Anchorage.*

3:40 PM - 4:30 PM

High energy cosmic rays arrive at Earth's upper atmosphere from all directions with a remarkably smooth power-law spectrum. Structures in this otherwise smooth spectrum (such as changes in slope or in chemical composition) give clues as to the sources, acceleration, and propagation of these particles. At energies beyond 1 PeV, as cosmic rays become too rare for direct measurements to be practical, large ground-based experiments make indirect measurements of cosmic ray air showers. They employ a wide range of detection technologies and techniques, exploring known features in the spectrum such as the "knee" and the "ankle", as well as searching for new clues in the energy spectrum, chemical composition, and anisotropy in arrival directions of these particles. This talk will overview the broad landscape of ground-based cosmic ray detector arrays, and will focus on the IceCube Observatory at the South Pole.

325 – The Plasma Physics of Cosmic Rays

Invited Session – Ballroom B, Dena'ina Center – 6/12/2012 4:30:00 PM to 6/12/2012 5:20:00 PM

325.01 – **The Plasma Physics of Cosmic Rays**

Ellen Gould Zweibel[1]

[1]*Univ. of Wisconsin.*

4:30 PM - 5:20 PM

Cosmic rays are responsible for some of the most energetic emissions in the Universe, and new tools for studying them abound. Cosmic rays play a key role in galactic gas dynamics and energy balance, and allow us to probe galactic and intergalactic magnetic fields both in the present epoch and over cosmic time. The acceleration and propagation of high energy particles in astrophysical environments, and the mechanisms through which they interact collectively with the host medium, are largely plasma physics phenomena. I will briefly review some salient aspects of cosmic ray astrophysics, and describe recent progress in understanding cosmic ray plasma physics.

326 – SPD Members' Meeting

Town Hall – Room 5, Dena'ina Center – 6/12/2012 6:00:00 PM to 6/12/2012 8:00:00 PM

Hear about the activities of the Solar Physics Division and AAS, get the latest news from agency representatives, congratulate the popular writing award winners, and meet your new leaders at the Members' Meeting at 6 p.m. on Tuesday, June 12.

327 – Public Talk: The Accelerating Universe

Invited Session – Ballroom B, Dena'ina Center – 6/12/2012 8:00:00 PM to 6/12/2012 9:00:00 PM

327.01 – **The Accelerating Universe**

Brian P. Schmidt[1]

[1]*RSAA, ANU, Australia.*

8:00 PM - 9:00 PM

In 1998 two teams traced back the expansion of the universe over billions of years and discovered that it was accelerating, a startling discovery that suggests that more than 70% of the cosmos is contained in a previously unknown form of matter, called Dark Energy. The 2011 Nobel Laureate for Physics, Brian Schmidt, leader of the High-Redshift Supernova Search Team, will describe this discovery and explain how astronomers have used observations to trace our universe's history back more than 13 billion years, leading them to ponder the ultimate fate of the cosmos.

328 – Nearby Stars and Brown Dwarfs

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

328.01 – **Quantification Of Errors In The Hipparcos Catalog**

Gregory S. Hennessy[1], R. Dudik[1], B. Dorland[1], N. Zacharias[1], V. Makarov[1]

[1]*U.S. Naval Obs..*

9:00 AM - 6:30 PM

The HIPPARCOS Catalog (Perrymann, et al. 1997) produced positions, proper motions, and parallaxes to the milliarcsecond for almost 120,000 objects. Over the last fifteen years much research has accrued from HIPPARCOS astrometry, including the cosmic distance scale, kinematic motions of the solar neighborhood, precise luminosities for stellar motions, and confirmation of the Einstein prediction on deflection of starlight. However the errors on the astrometric values provided in this widely used catalog have degraded over time. The current state of the art in ground based observations allow us to attempt to quantify the errors in the proper motions of HIPPARCOS stars. This poster outlines the moving cluster methodology we have used to estimate the astrometric errors on HIPPARCOS stars as well as calculated effect on HIPPARCOS position, proper motion and parallax accuracies.

328.02 – **Energy Conservation And Gravity Waves In Stellar Interior Simulations That Employ Sound-proof Treatments**

Benjamin Brown[1], G. M. Vasil[2], D. Lecoanet[3], E. G. Zweibel[1]

[1]*Univ. of Wisconsin - Madison,* [2]*Candian Institute for Theoretical Astrophysics, Canada,* [3]*University of California, Berkeley.*

9:00 AM - 6:30 PM

In the deep stellar interiors, flows are typically much slower than the local speed of sound. Owing to this, simulations of stellar convection and dynamo action typically employ various "sound-proof" equations, which filter the fast sound waves but can follow the subsonic convective flows. These sound-proof equations include the anelastic equations, which typically are derived in adiabatically-stratified stellar convection zones, and the pseudo-incompressible equations. In stars like the Sun, the radiative zone underlying the convection zone is a region of stable subadiabatic stratification, where motions remain highly subsonic and gravity waves dominate the dynamics. We study the application of sound-proof equations to dynamics in stellar radiative zones. We find that some formulations fail to conserve energy in regions of stable stratification and consequently do not correctly capture the dynamics of gravity waves. We provide a mapping to equations that do conserve energy. We discuss gravity wave dynamics in stably-stratified stellar regions in the context of simulations of stars like the Sun, and also consider more massive stars, where the radiative envelope lies above a convective core.

328.03 – **Simultaneous Photometric and Spectroscopic Observations of Young Solar Analogs**

Jon M. Saken[1], R. O. Gray[2], C. J. Corbally[3]

[1]*Marshall University,* [2]*Appalachian State University,* [3]*Vatican Observatory Research Group.*

9:00 AM - 6:30 PM

This poster will present some preliminary results, focusing on the relationship

between chromospheric activity level and stellar brightness, from our long-term monitoring campaign conducting simultaneous spectroscopic and photometric observations of young stellar analogs (YSAs). Since 2007 we have been conducting spectroscopic monitoring of the Ca II H & K lines for a sample of 31 YSAs in order to better understand their activity cycles and variations, as well as the effects of young stars on their solar systems. The targets cover the spectral range of stars most likely to contain Earth analogs, F8-K2, and a broad enough range of ages, 0.3 Gyr - 1.5 Gyr, to investigate how activity level changes with stellar age. These studies are already showing possible evidence for activity cycles, large variations in starspot activity, and flaring events. In order to obtain a more complete picture of the nature of the stars'

activity and examine the correlations between stellar brightness and chromospheric activity, we recently began simultaneous photometric observations of the stars in Johnson B, V and R. Some stars, such as the Sun, show a positive correlation with brightness and activity level. Yet the Lowell Observatory SSS project showed that many G0-G2 type YSAs show a negative correlation. Of particular interest for our project is the determination of which stars show either a positive or negative correlation and characterizing how this changes with stellar age. Results from the first season of observations are presented here. Starting this year we will be adding two new instruments to provide improved temporal coverage and additional data in Stromgren *v* and Hα.

Support provided by the NSF.

328.04 – **The Old Feeble Transition Regions and Coronae of Solar-like Dwarf Stars in the Arcturus Moving Group**

Alexander Brown[1], E. J. Hodges-Kluck[2], T. R. Ayres[1], G. M. Harper[3]
[1]*Univ. of Colorado,* [2]*Univ. of Michigan,* [3]*Trinity College Dublin, Ireland.*
9:00 AM - 6:30 PM

Old dwarf stars have generally spun down significantly thus dampening one of the main contributors (rotation) to solar-like alpha-omega magnetic dynamo activity. Studying how stellar activity on stars older than the Sun changes in terms of the chromospheric/transition-region/coronal temperature structure and how much energy is radiated as a function of temperature provides important constraints on how solar-like dynamos work. Stars with different metallicities provide information on how the radiative cooling channels control the temperature structure.

We have measured fluxes and profiles of FUV emission lines using the HST COS spectrograph and the broad-band X-ray fluxes using Chandra ACIS-S for a sample of old inactive dwarfs. Our sample comprises five members of the 7-8 Gyr Arcturus Moving Group --- HD90508/LHS2266 (F9 V/M4 V, [Fe/H] = -0.4), HD65583 (G8 V, Fe/H]=-0.7), and HD145417 (K0 V, [Fe/H]=-1.4) --- plus three well-studied comparison stars -- HD103095 (G8 V, [Fe/H]=-1.4), Tau Ceti (G8 V, [Fe/H]=-0.4), and the Quiet Sun (G2 V, [Fe/H]=0.0).

In this poster we provide estimates of atmospheric radiative losses as a function of temperature and metallicity. The atmospheres of these low-metallicity stars are more heavily weighted towards cooler temperatures than those of more active stars or even the Sun. Chromospheric emission lines, e.g. C I lines, are far stronger relative transition region lines, e.g C IV. Similarly the X-ray data provide detections for all the targets but with primarily very soft (0.3-0.5 keV) photons and imply "coronal" temperatures of less than 1 MK. While the temperature distributions are cooler, the overall integrated X-ray and FUV luminosities are similar to those of the "Quiet Sun" -- implying that similar amounts of non-radiative energy input are being dissipated.

This work is supported by NASA GALEX grant NNX06AB46G, HST grants GO-11555 and GO-11829, and Chandra grants GO6-7018X, GO7-8020X, and GO9-0021X to the University of Colorado.

328.05 – **A Cast of Characters in the Solar Neighborhood**

Todd J. Henry[1], S. B. Dieterich[2], W. Jao[2], A. R. Riedel[2], J. P. Subasavage[3], J. G. Winters[2], RECONS
[1]*RECONS,* [2]*RECONS / Georgia State University,* [3]*RECONS / USNO.*
9:00 AM - 6:30 PM

What in the stars is going on?

Since 1999, the RECONS (REsearch Consortium On Nearby Stars,

www.recons.org) team has been using the CTIO 0.9m to carry out a large astrometry/photometry program. We are measuring VRI photometry for more than 2000 stars, parallaxes for more than 600 stars, and making long-duration positional measurements of more than 100 stars to reveal hidden companions. Careful observations of so many stars occasionally yields bizarre results. Here we unveil a cast of characters who are the oddest of the odd --- twins who seem to have been born at different times, a baby star on the Sun's doorstep, and dark companions that lurk in the shadows unseen. Unraveling these puzzling stellar systems promises not only challenges, but perhaps new astrophysical insight to stellar formation and evolution. As Hamlet would say, understanding these systems "tis a consummation devoutly to be wished," but these characters certainly do give us pause in the meantime.

This effort is supported by the NSF through grant AST-0908402 and via observations made possible by the SMARTS Consortium.

328.06 – **Rotational Modulation, Shear, And Cyclic Activity In HII 2927**

Jackie Milingo[1], S. H. Saar[2], S. L. Lehman[1], L. A. Marschall[1], J. R. Stauffer[3]
[1]*Gettysburg College,* [2]*SAO,* [3]*Spitzer Science Center.*
9:00 AM - 6:30 PM

We present a 15 yr compilation of V-band differential photometry for the Pleiades K4 dwarf HII 2927 (V378 Tau). HII 2927 has a rotational period (P_rot) of ~ 0.26 d and displays significant rotational modulation due to non-uniform surface brightness or "starspots". With the long timeline of data available we can explore many aspects of the star's photometric variability, with the goal of including them in a larger study of magnetic activity in single cool dwarfs. Preliminary work yields a cycle period (P_cyc) of 14.5 +/- 1.9 yrs. We also present preliminary work on the rotational shear for this star (ΔP_rot/<P_rot>). Measurements of P_cyc and rotational shear contribute to our understanding of the magnetic dynamo at the source of stellar activity. We compare our P_cyc and ΔP_rot/<P_rot> estimates with those of other stars, including our measurements of fellow Pleaid HII 1883 (V660 Tau).

328.07 – **Anchoring dM Star Age-Rotation-Activity Relationships and Assessing Planetary Habitability**

Scott G. Engle[1], E. Guinan[1], A. Marion[1]
[1]*Villanova University.*
9:00 AM - 6:30 PM

Red Dwarf (dM) stars make up over 75% of the local stellar population. This is among the reasons they are being targeted in more planet-hunting programs. The ability to accurately estimate the age of a field dM star is of critical importance. However, due to their long lifetimes, and very slow nuclear evolution, the best method for determining ages would seem to be through “magnetic tracers” such as X-UV activity levels and stellar rotation rates. The *Living with a Red Dwarf Program’s* database of dM stars with photometrically determined rotation periods (from starspot modulations) is becoming substantial. It has recently been expanded to include dM stars with well-detached WD companions - through which reliable ages can be determined. When combined with dM stars possessing cluster/population memberships, or specific kinematics, a full range of “calibrators” is being realized. We report on our continuing efforts to build reliable Age-Rotation-Activity relationships for dM stars. Such relationships permit the assessment of the habitability of planets hosted by red dwarfs, by delineating the X-UV radiation environments these planets are exposed to, and have been exposed to in the past. After proper calibration, the relationships can also permit the age of a field red dwarf (and their hosted planets) to be determined through measures of either its rotation period or X-UV activity level.

We gratefully acknowledge the support from NSF/RUI Grant AST 1009903 and Chandra Grants GO1-12124X and GO2-13020X.

328.08 – **An SB1 with a Brown Dwarf Component in a Very-Low Mass Triple System**

Daniella Bardalez Gagliuffi[1], A. J. Burgasser[1], C. Luk[1], L. Prato[2], S. Dhital[3], C. Nicholls[1], A. A. West[4], C. Melis[1], S. Lepine[5]
[1]*University of California, San Diego,* [2]*Lowell Observatory,* [3]*Vanderbilt University,* [4]*Boston University,* [5]*American Museum of Natural History.*
9:00 AM - 6:30 PM

We report the identification of the M9 dwarf SDSS J000649.16-085246.3 as part of a tightly-separated brown dwarf binary within a low-mass triple system with the M7 star LP 704-48 as a widely-separated (~600 AU) third component. Low-resolution spectral data from IRTF/SpeX show subtle spectral features typical of a T dwarf companion, and spectral template fitting indicates component types of M8.5 and T5±1 for the tight binary. Multi-epoch high-resolution spectra from Keck/NIRSPEC, taken over 16 months, show RV variability with an amplitude of 9 km/s, and orbital fits reveal a nearly circular orbit with a period of ~150 days and semi-major axis of ~0.2 AU. The absence of H alpha emission in the M7 primary suggests a minimum age of ~7 Gyr, which with the radial velocity orbit provides stringent constraints on the masses of SDSS J000649.16-085246.3A and B. Hierarchical multiple systems like this one provide an ideal benchmark for the study of brown dwarf formation.

328.09 – **A USNO Search for Astrometric Companions to Brown Dwarfs II**

Jennifer L. Bartlett[1], F. J. Vrba[1], J. A. Munn[1], C. B. Luginbuhl[1], T. Tilleman[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 June over periods from 2.0 to 5.8 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 enables 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 mid-L through late-T ranges. None are known binaries. Preliminary parallaxes place them within 42 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 9^h and 19^h in R.A.

The brown dwarfs evaluated are 2MASS J09373487+2931409, 2MASS J09393548-2448279, 2MASSW J1047539+212423, 2MASS

J11145133-2618235, 2MASS J12171110-0311131, 2MASS J12373919+6526148, 2MASS J15031961+2525196, 2MASS J15232263+3014562, 2MASS J16322911+1904407, and 2MASS

J18410861+3117279. Analyses of another 10 brown dwarfs was presented earlier and the analyses of 29 more brown dwarfs are planned.

328.1 – **The Brown Dwarf Kinematics Project (BDKP): Radial and Rotational Velocities for 50 T dwarfs with FIRE**

Adam J. Burgasser[1], C. Nicholls[1], J. Bochanski[2], J. Faherty[3], A. West[4], R. Simcoe[5]
[1]*UC San Diego,* [2]*Pennsylvania State University,* [3]*Universidad de Chile, Chile,* [4]*Boston University,* [5]*MIT.*
9:00 AM - 6:30 PM

The kinematics of nearby stars provide statistical constraints on the age of our local population and identify members of distinct kinematic groups, including thick disk/halo stars and members of local moving associations. For brown dwarfs, these measurements also provide independent age constraints useful for calibrating empirical gravity diagnostics and testing evolutionary models. For T-type brown dwarfs, radial velocity measurements for kinematics have been stymied by sensitivity limits. Here we present moderate-resolution (R ≈ 6000) near-infrared spectroscopy for 50 T dwarfs observed with the Folded Port Infrared Echellette (FIRE) mounted on the 6.5m Magellan Baade Telescope. The forest of molecular lines resolved by these spectra allow the measurement of radial velocities with <1-3 km/s precision, and rotational velocities when V sin i > 20 km/s. Combining these data with proper motion and parallax measurements compiled by BDKP, we examine 6D spatial-kinematic distributions of the local T dwarf population, quantifying trends between, e.g., velocity spread and near-infrared color excess (related to surface gravity and metallicity effects). We also report the identification of both old, thick disk brown dwarfs and eccentric Galactic orbits; and young planetary-mass candidate members of nearby moving groups. We examine how velocity dispersions vary between local M, L and T dwarfs, and demonstrate how these track evolutionary trends in the Galactic brown dwarf population. Finally, we report multi-epoch radial velocity measurements for 5 systems suspected of being unresolved spectral binaries.

328.11 – **L Dwarfs in the Catalina Real-time Transient Survey: Beats And Freaks**

Amelia Christensen[1], A. Burgasser[1], A. Drake[2], G. Hallinan[2]
[1]*UC San Diego,* [2]*Caltech*.
9:00 AM - 6:30 PM

L dwarfs are a class of low-temperature, low-mass stars and "failed" stars (aka brown dwarfs), objects incapable of fusing hydrogen in their cores. Their atmospheres are typically too cool to form magnetic spots, but they are known to form metal and mineral clouds in their photospheres. Such clouds may show asymmetries across the surfaces, which can produce both periodic (due to rotation) and aperiodic (due to cloud evolution) photometric variability. To search for such variations, we have been analyzing long-term visual-band photometry contained in the Catalina Real-Time Transient Survey (CRTS, Drake et al. 2009). For V < 19 sources, CRTS contains hundreds of brightness and position measurements per source spanning a half-decade, allowing us to search for periodic variations spanning hours to years. We report our selection strategy, including the determination of mean V-J, V-H and V-Ks colors as a function of spectral type; and the weeding out of blends. We report preliminary results for two variable multiple sources, the J0746+20 AB binary, for which we detect the "beat" frequency of rotational periods from the individual components; and Kelu-1, which exhibits a complex lightcurve potentially arising from both periodic and aperiodic variations among its three components.

328.12 – **Near-Infrared Variability in L and T Dwarfs: Are Some Spectral Binary Candidates Just "Patchy"?**

Harish G. Khandrika[1], A. J. Burgasser[1], C. Melis[1], E. Bowsher[2], B. Swift[3]
[1]*University of California San Diego,* [2]*Columbia University,* [3]*University of Arizona*.
9:00 AM - 6:30 PM

Using the Gemini infrared camera on the 3-meter Shane telescope at Lick Observatory, we have searched for broad-band J and K' photometric variability for a sample of 15 L and T-type brown dwarfs, including 7 suspected spectral binaries. Four of the dwarfs - 2MASS J0939-2448, 2MASS J1511+0607, 2MASS J1711+2232, and 2MASS J2139+0220 - exhibit statistically significant variations over periods ranging from 1 hour to 6 days. Our detection of variability in 2MASS J2139+0220 confirms that reported by Radigan et al., and Lomb-Scargle periodogram analysis indicates a variability period of approximately 7.42 ± 0.23 hours, coincident with the findings of Radigan et al. Remarkably, three of the four variables are candidate spectral binaries, but high-resolution spectroscopic observations of 2MASS J2139+0220 with Keck/NIRSPEC indicate no significant radial velocity variations. This result suggests that the features associated with some spectral binary candidates may arise from blends of cloudy and non-cloudy regions in particularly "patchy" atmospheres.

329 – Binary Stellar Systems, X-ray Binaries

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

329.01 – **Observation and Analysis of the Dwarf Solar type Classic Algol Binary V1043 Cassiopeia**

Ronald G. Samec[1], P. M. Smith[1], D. R. Faulkner[2], W. Van Hamme[3]
[1]*Astronomy program, Bob Jones Univ.,* [2]*University of South Carolina,* [3]*Department of Physics, Florida International University.*
9:00 AM - 6:30 PM

Complete Bessel BVRI light curves of V1043 Cassiopeia [2MASS J00371195+5301324, Mis V1292, USNO-A2.0 1425-00875743, α(2000) = 00h 37m 11.95s, δ(2000) = +53° 01′ 32.5″] are analyzed. The analysis includes a period study, an improved ephemeris, a mass ratio search, and a simultaneous BVRI Wilson-Devinney solution. This work results from a Fall and Spring 2011-2012 research program arising from a professional-undergraduate student-collaboration.

The Bessel B, V, R, I light curves were taken were taken on 28 and 29 September, 2010 at Lowell Observatory with the 0.81-m reflector with NURO time. Our observations were taken with the CRYOTIGER cooled (<-100C) 2KX2K CCD NASACAM.

Four new precision times of minimum light were calculated from our observations using parabolic fits:

HJD I = 2455467.6564 (±0.0009)d, 2455468.9869 (±0.0039)d

HJD II= 2455467.3972 (±0.0006)d, 2455468.6493 (±0.0028)d

along with several from MISAO data. The improved ephemeris,

HJD Tmin I = 24555467.6567 ± 0.0010 + 0.66158617 ± 0.00000047d*E

was calculated from 10 eclipse timings.

GSC 3654 0269 and GSC 3654 0185 were used as comparison and check star, respectively. A primary component temperature of 5000 K was concluded from JHK 2MASS photometry.

The curves were pre-modeled with Binary Maker 3.0, followed by simultaneous 4 color synthetic light curve solutions with the Wilson-Devinney program. After an initial solution was determined, we performed a mass ratio search which minimized at ~0.6. The high amplitude light curves gave an inclination of 82 degrees. The secondary component modeled at 3827±1 K.

V1043 Cas is an early K-type, dwarf binary with an M0-type secondary. It is surprisingly, a detached binary system rather than an EW contact binary. Indeed, it could be classified as a precontact W UMa Binary. The mass ratio is 0.65 and fill-outs are 72%, 79% of its critical lobes for the primary and secondary components, respectively.

329.02 – **H-alpha/H-beta and Optical Monitoring of High Mass X-ray Binary Systems**

Eric G. Hintz[1], M. D. Joner[1]
[1]*Brigham Young Univ.*.
9:00 AM - 6:30 PM

We have developed a new fully calibrated H-alpha index, defined on both spectroscopic and photometric measurements of bright stars. Using the new H-alpha index, along with the traditional H-beta index, and optical broad band filters, we have monitored a set of High Mass X-ray Binary systems. In a number of cases we have seen significant variation in the H-alpha index, while there is limited variation in H-beta and/or the broad band filters. In one extreme case we see a 0.5 magnitude change in the H-alpha index in only 45 minutes, while H-beta and the optical flux remain constant. We will present results for a number of systems including 4U 2206+54, 1H 1936+541, 1H 2202+501, 4U 1956+35, IGR J00370+6122, RX J0440.9+4421, RX J2030.5+4751, and XTE J0421+560. This work is partially supported by NSF Grant AST-0618209. We also acknowledge use of the facilities of the Dominion Astrophysical Observatory.

329.03 – **A Search for Gamma-Ray Emission from Variable Galactic Radio Sources**

Chris R. Shrader[1], D. J. Macomb[2]
[1]*NASA's GSFC,* [2]*Boise State University.*
9:00 AM - 6:30 PM

We describe our ongoing program using data obtained with the Fermi Gamma-Ray Space Telescope as well as with Swift and INTEGRAL to search for gamma-ray hard-X-ray and emission from several recently published surveys of galactic radio sources. Radio emission was established as a ubiquitous property of gamma ray sources prior to the launch of Fermi. Subsequent examination of the composition of the two year source catalog of that mission, comprising some 1900 individual sources, further supports this idea. Known classes of galactic variable radio sources include high-mass X-ray binaries such as Cyg X-3 and LSI +61 303 which are already established gamma-ray emitters. Those objects are often transient in nature and they are often revealed through survey observations in the hard-X-ray band. Additional objects among this class may be revealed and establishing them as gamma-ray emitters would be of great interest. Other possible source classes include radio-loud magnetars, RRATs (Rotating Radio Transients) and flare stars. Most interestingly, totally unexpected phenomena could also be revealed. We will describe our sample selection, data extraction and analysis methods and present results obtained to date, including several promising candidates.

329.04 – **The Near Contact System EG Cephei**

Ronald J. Angione[1], J. R. Sievers[2]
[1]*San Diego State Univ.,* [2]*San Diego Mesa College*.
9:00 AM - 6:30 PM

We present the first simultaneous four color Stromgren photometric and spectroscopic orbit solution of EG Cephei (V = 9.44, P = 0.545 days). This system is known to have a variable period. However, we found no spectroscopic evidence

of active mass transfer. Our spectroscopic orbit of the primary component yielded a semi-amplitude of K_1 = 111 km/sec. Our photometric solution, using the Wilson-Devinney and ELC modeling programs, suggests EG Cephei is a spotted β Lyr system. We determined the masses and radii, in solar units, to be M_1 = 1.59, M_2 = 0.75, R_1 = 1.62, R_2 = 1.17, and the temperatures to be T_1 = 8000K, and T_2 = 5441K.

329.05 – **A Very Short Period M dwarf Binary from the SDSS Stripe 82**

James R. A. Davenport[1], A. C. Becker[1]

[1]*University of Washington.*

9:00 AM - 6:30 PM

We present follow-up observations and analysis of the 0.1986 day low-mass eclipsing binary, SDSS J001641-000925. This system belongs to a very rare class of near contact eclipsing stellar binaries below the theoretical short period limit, and has one of the shortest known periods for an M dwarf binary system. Using medium-resolution spectroscopy and multi-band photometry for the system we have determined that SDSS J001641-000925 is the best candidate for a contact low-mass binary yet found.

329.06 – **Direct Impact Accretion in Double White Dwarf Binary Systems**

Kyle Kremer[1], J. Sepinsky[2], V. Kalogera[1]

[1]*Northwestern University,* [2]*The University of Scranton.*

9:00 AM - 6:30 PM

In close mass-transferring binary systems, it is commonly assumed that direct impact accretion provides a strong sink of orbital angular momentum. In double white dwarf binaries, the accreting star is large compared to the orbital separation, making these systems ideal for the occurrence of direct impact accretion. Here we present an alternative analysis of direct impact accretion in double white dwarf binaries. For such a system, we assume that a continuous mass ejection stream can be approximated as a discrete, massive particle ejected at a single point in the orbit through the inner Lagrangian point of the donor star. After validating this assumption, we proceed to calculate the evolution of the orbital elements of the system through three-body integration. Additionally, we improve upon previous analytic analyses by allowing for asynchronicity between the spins of the accretor and the orbit as well as the donor and the orbit. This generalization introduces tidal coupling terms for both the accretor and the donor which will affect the exchange of orbital angular momentum between the stars and the orbit. We show that, contrary to popular assumptions, angular momentum need not be removed from the orbit in all cases of direct impact accretion. This result has significant impact upon the stability of close white dwarf binaries.

329.07 – **Mapping the Amplitude Distribution of Cepheid Orbits**

Nancy Remage Evans[1], J. Nichols[1], D. Morgan[1], B. Sundheim[1], L. Berdnikov[2], N. Gorynya[2], A. Rastorguev[2], P. Moskalik[3], J. Lauer[1]

[1]*SAO,* [2]*Sternberg Astronomical Institute of the Moscow State University, Russian Federation,* [3]*Copernicus Institute, Poland.*

9:00 AM - 6:30 PM

Cepheids are an intermediate mass star (typically 5 Msun) with narrow spectral lines for determining radial velocities. This feature--unique among massive stars--means they are sensitive to small amplitude orbital motion due to long periods and/or low mass companions. A number of groups have made extensive radial velocity observations over the last 30 years, in particular the Moscow University group and groups using CORAVEL. We are developing a sample culled from this data of stars with a long time sequence of velocities with errors of typically +/- 1 km/s to search for long period orbital motion, and conversely to identify stars showing no orbital motion. To do this, particular care is required in obtaining the correct pulsation period and an analytic representation of the pulsation velocity curve (typically a fourier series). A database is being created to assess the data strings and identify appropriate stars to determine the frequency of low amplitude orbital motion.

Financial support was provided by the Chandra X-ray Center NASA contract NAS8-03060.

329.08 – **Identifying the X-ray Source Population of our Nearest Starburst.**

Silas Laycock[1], A. Balchunas[1], R. Cappallo[1], K. Oram[1], A. Prestwich[2], B. Williams[3], A. Camero-Arranz[4]

[1]*UMass Lowell,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*University of Washington,* [4]*USRA.*

9:00 AM - 6:30 PM

The dwarf starburst Galaxy IC 10 provides an ideal laboratory to understand young X-ray binary populations. The mass-scaled star formation rate of IC 10 is the highest in the local universe, leading to an unrivaled surface density of massive stars and their evolutionary products. The angular extent of IC 10 fills a single field of view for both Chandra and Gemini, enabling a multi-wavelength whole-galaxy survey. The results of our 2003-10 X-ray monitoring sequence, combined with follow-up Gemini narrow/broad band optical imaging and MOS spectroscopy include: X-ray light-curves, spectra, and variability statistics, and identifications of HMXBs, supernova remnants, and foreground coronae. Among the variable X-ray sources discovered (~20% of 111 point sources) is a large amplitude logLX=35-37 erg/s recurrent transient with an apparent supergiant counterpart. This object shows similarities to the supergiant fast X-ray transient (SFXT) class recently identified in the Milky Way.

329.09 – **High Mass X-ray Binaries In The Mid-infrared**

Stefanie Wachter[1]

[1]*Caltech.*

9:00 AM - 6:30 PM

High mass X-ray binaries (HMXBs) are stellar systems composed of a compact object, either a neutron star or black hole, accreting matter from a massive OB type companion. HMXBs are strong tracers of recent star formation, but the various factors that influence the formation of HMXBs are not well understood. For example, the SMC has a much larger than expected number of HMXBs compared to the Milky Way based on the mass ratio for the two galaxies. We present a comprehensive look at the near to mid-IR emission of these objects utilizing 2MASS, Spitzer, and WISE data. The particular goals of our study are: to establish the mid-IR spectral energy distribution, to search for the signatures of infrared excess and episodes of mass loss, and to study the local environment of these sources.

329.1 – **A Showcase of Unique Binary Systems Discovered by the Kepler Satellite**

Brian Kirk[1], A. Prsa[2], K. Conroy[2], S. Bloemen[3], A. Shporer[4], T. Barclay[5], K. Hambleton[6], J. Devor[7], K. Kinemuchi[8], B. Fulton[4]

[1]*Eastern University,* [2]*Villanova University,* [3]*Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Belgium,* [4]*Las Cumbres Observatory Global Telescope Network,* [5]*Armagh Observatory, Ireland,* [6]*Jeremiah Horrocks Institute, United Kingdom,* [7]*Harvard-Smithsonian Center for Astrophysics,* [8]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

The importance of eclipsing binaries in modern astrophysics ranges from deriving fundamental stellar parameters across the Hertzsprung-Russell Diagram and calibrating the mass-radius-temperature relationships to determining the distances in the Galaxy and beyond. The unprecedented quality and uninterrupted sampling of Kepler data with sub-millimag precision are a leap forward in observational capabilities and enable us to perform modeling and analysis of these systems to an unparalleled precision. Currently the Kepler mission is providing a nearly seamless stream of photometric data of approximately 2500 eclipsing binary stars in its 105-square degree field of view. The Kepler Eclipsing Binary (EB) catalog is continuously being augmented as more data are collected and EBs are being detected at longer periods. The quarterly data segments for the entire mission are “stitched” together and detrended by fitting a variable order Legendre series to the light curve baseline. Each system is then classified into a morphology type by the method of Locally Linear Embedding. By fitting a polynomial chain to the data an analytic representation is obtained and passed through a trained artificial neural network to yield the remaining parameters. The catalog now contains more than six times the number of EB systems originally observed in the Kepler FOV. This high-precision instrument holds great promise for the discovery of many objects and we present here a showcase of unique objects from the Q0 through Q9 data release.

329.11 – **New Photometric Study of the Interacting Binary Star System: Y Piscium**

Bernard J. Yuhas[1], T. Coleman[1], P. A. Reed[1]

[1]*Kutztown University.*

9:00 AM - 6:30 PM

We present a new photometric study of Y Psc, which is an Algol-type interacting binary system with an orbital period of 3.76 days and a nonlinear ephemeris.

The Kutztown University Observatory (Kutztown, Pa), which houses a 0.46 meter modified Cassegrain telescope, was used to perform a photometric study of Y Psc. Data were collected over 18 nights of observation, which started on the 5th of October 2011 and ended on 15th of January 2012. Three different Bessel filters: Blue, Visual, and Infrared were used to analyze the system. These data were then compiled and modeled using the Wilson-Devinney code. An Analysis of previously recorded times of minimum in conjunction with our observations were used to suggest possible physical mechanisms intrinsic to the system.

329.12 – **The First CCD Light Curves of BO Monocerotis**

Thomas Coleman[1], B. Yuhas[1], P. A. Reed[1]

[1]*Kutztown University.*

9:00 AM - 6:30 PM

We present new light curves of BO Monocerotis. BO Mon is an interacting Algol-type binary system with a 2.22 day orbital period that undergoes interesting variations.

Kutztown University's 0.46-meter Cassegrain telescope was employed for this photometric study of BO Mon. The data were collected over 13 nights between 3 January 2012 and 18 February 2012 with B,V, and I filters. Using the Wilson-Devinney code, we modeled the system and found a unique orbital solution. In addition, our period study suggests a possible mechanism to explain the oscillations in its ephemeris curve.

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330 – Kepler Mission

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

330.01 – **Keeping Up With The Planets: Scaling Kepler's Data Analysis Pipeline To Handle An Increasingly Complex Volume Of Astronomical Data.**

Todd C. Klaus[1], M. T. Cote[2], F. Girouard[1], S. D. McCauliff[1], C. Henze[2], J. D. Twicken[3], J. Li[3], P. Tenenbaum[3], S. Seader[3], B. D. Clarke[3], E. V. Quintana[3], J. M. Jenkins[3], D. A. Caldwell[3]

[1]*Orbital Sciences Corporation,* [2]*NASA Ames Research Center,* [3]*SETI Institute.*

9:00 AM - 6:30 PM

NASA's *Kepler* Space Telescope has collected data on over 190,000 targets (and counting) since launch on March 6th, 2009, resulting in a growing dataset that must be processed by the *Kepler* Science Pipeline. The algorithms that make up the pipeline are responsible for clearing the chaff of instrumental and astrophysical noise to detect and model the transit-like signals hidden underneath. We discuss how the *Kepler* pipeline infrastructure has evolved to meet the growing computational needs of these algorithms.

The algorithms and other support software that make up the pipeline were largely developed before launch and tested with simulated data. When confronted with flight data from the *Kepler* instrument, the pipeline revealed that the higher than expected thermal sensitivity of the instrument, electronics noise and operational procedures all introduced artifacts to the data at levels comparable to, or higher than the sought after transit signals. In the months after launch the team of pipeline developers at the *Kepler* Science Operations Center (SOC) at NASA Ames Research Center toiled to update the pipeline software to identify and mitigate these artifacts where possible, work that continues today.

The increase in complexity caused by these algorithm changes, along with a need for regular reprocessing of a growing dataset to support scientific data analysis and pipeline development created an increasing demand for computing resources. This need in turn drove the need for changes to the pipeline infrastructure software to extend pipeline algorithm execution to NASA's Advanced Supercomputer (NAS). Use of the NAS as a computing resource allows the pipeline operator to spread the planetary transit search and data validation jobs across tens of thousands of processing cores. With a possible extended mission on the horizon, this need will only grow, and work to port the rest of the pipeline to the NAS has already begun.

330.02 – **Dynamic Black-Level Correction and Artifact Flagging for Kepler Pixel Time Series**

Bruce Clarke[1], J. J. Kolodziejczak[2], D. A. Caldwell[1]

[1]*SETI,* [2]*NASA Marshall Space Flight Center.*

9:00 AM - 6:30 PM

Instrument-induced artifacts in the raw *Kepler* pixel data include time-varying crosstalk from the fine guidance sensor (FGS) clock signals, manifestations of drifting moiré pattern as locally correlated nonstationary noise and rolling bands in the images which find their way into the calibrated pixel time series and ultimately into the calibrated target flux time series. As the *Kepler Mission* continues to improve the fidelity of its science data products, we are evaluating the benefits of adding pipeline steps to more completely model and dynamically correct the FGS crosstalk, then use the residuals from these model fits to detect and flag spatial regions and time intervals of strong time-varying black-level which may complicate later processing or lead to misinterpretation of instrument behavior as stellar activity.

The FGS crosstalk pixels are present in 20-25% of targets but typically vary slowly enough to create a very small risk of reduced sensitivity or increased false positive rate in the transit search. However, they do have the potential to complicate or reduce the effectiveness of cotrending algorithms by introducing additional cotrending terms into the light curves which are not associated with prior relations. We will present results regarding the improvement in cotrending performance as a result of including FGS corrections in the calibration.

The rolling bands appear in only ~10% of channels and are present only in 3% of the total exposure, but we estimate that, because of the rotation of stars through the affected sky groups, about 30% of light curves are ultimately affected. Thus the utility of rolling band flagging is expected to be high. We will discuss the effectiveness of the proposed flagging and illustrate with some affected light curves.

Funding for the *Kepler Mission* has been provided by the NASA Science Mission Directorate.

330.03 – **Removing the Noise and Systematics while Preserving the Signal - An Empirical Bayesian Approach to Kepler Light Curve Systematic Error Correction**

Jeffrey C. Smith[1], M. C. Stumpe[1], J. Van Cleve[1], J. M. Jenkins[1], T. S. Barclay[2], M. N. Fanelli[2], F. Girouard[3], J. Kolodziejczak[4], S. McCauliff[3], R. L. Morris[1], J. D. Twicken[1]

[1]*SETI Institute/NASA Ames Research Center,* [2]*Bay Area Environmental Research Institute / NASA Ames Research Center,* [3]*Orbital Sciences Corporation / NASA Ames Research Center,* [4]*Marshall Space Flight Center.*

9:00 AM - 6:30 PM

We present a Bayesian Maximum A Posteriori (MAP) approach to systematic error removal in Kepler photometric data where a subset of highly correlated and quiet stars is used to generate a cotrending basis vector set which is, in turn, used to establish a range of "reasonable" robust fit parameters. These robust fit parameters are then used to generate a "Bayesian Prior" and a "Bayesian Posterior" PDF (Probability Distribution Function). When maximized, the posterior PDF finds the best fit that simultaneously removes systematic effects while reducing the signal distortion and noise injection which commonly afflicts simple Least Squares (LS) fitting. A numerical and empirical approach is taken where the Bayesian Prior PDFs are generated from fits to the light curve distributions themselves versus an analytical approach, which uses a Gaussian fit to the Priors. Recent improvements to the algorithm are presented including entropy cleaning of basis vectors, better light curve normalization methods, application to short cadence data and a goodness metric which can be used to numerically evaluate the performance of the cotrending. The goodness metric can then be introduced into the merit function as a Lagrange multiplier and the fit iterated to improve performance. Funding for the Kepler Discovery Mission is provided by NASA's Science Mission Directorate.

330.04 – **Multiscale Systematic Error Correction via Wavelet-Based Band Splitting and Bayesian Error Modeling in *Kepler* Light Curves**

Martin C. Stumpe[1], J. C. Smith[1], J. Van Cleve[1], J. M. Jenkins[1], T. S. Barclay[2], M. N. Fanelli[2], F. Girouard[3], J. Kolodziejczak[4], S. McCauliff[3], R. L. Morris[1], J. D. Twicken[1]

[1]*SETI Insitute / NASA Ames Research Center,* [2]*Bay Area Environmental Research Institute / NASA Ames Research Center,* [3]*Orbital Sciences Corporation / NASA Ames Research Center,* [4]*Marshall Space Flight Center.*

9:00 AM - 6:30 PM

Kepler photometric data contain significant systematic and stochastic errors as they come from the *Kepler* Spacecraft. The main cause for the systematic errors are changes in the photometer focus due to thermal changes in the instrument, and also residual spacecraft pointing errors. It is the main purpose of the Presearch-Data-Conditioning (PDC) module of the *Kepler* Science processing pipeline to remove these systematic errors from the light curves. While PDC has recently seen a dramatic performance improvement by means of a Bayesian approach to systematic error correction and improved discontinuity correction, there is still room for improvement. One problem of the current (*Kepler* 8.1) implementation of PDC is that injection of high frequency noise can be observed in some light curves. Although this high frequency noise does not negatively impact the general cotrending, an increased noise level can make detection of planet transits or other astrophysical signals more difficult. The origin of this noise-injection is that high frequency components of light curves sometimes get included into detrending basis vectors characterizing long term trends. Similarly, small scale features like edges can sometimes get included in basis vectors which otherwise describe low frequency trends. As a side effect to removing the trends, detrending with these basis vectors can then also mistakenly introduce these small scale features into the light curves. A solution to this problem is to perform a separation of scales, such that small scale features and large scale features are described by different basis vectors. We present our new multiscale approach that employs wavelet-based band splitting to decompose small scale from large scale features in the light curves. The PDC Bayesian detrending can then be performed on each band individually to correct small and large scale systematics independently.

Funding for the *Kepler* Mission is provided by the NASA Science Mission Directorate.

330.05 – **The *Kepler* Pipeline Data Validation Report: Coming Soon to the Exoplanet Archive**

Joseph D. Twicken[1], H. Wu[1], B. Wohler[2], F. Girouard[2], J. Li[1], B. D. Clarke[1], P. Tenenbaum[1], E. V. Quintana[1], T. Klaus[2], M. T. Cote[3], S. McCauliff[2], J. M. Jenkins[1], D. A. Caldwell[1], J. F. Rowe[1], S. T. Bryson[3], C. J. Burke[1]

[1]*SETI Institute,* [2]*Orbital Sciences Corporation,* [3]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

Kepler's automated Data Processing Pipeline identifies thousands of potential transiting planet candidates, known as Threshold Crossing Events. Many of these are instrument artifacts, eclipsing binaries, or other astrophysical false positives. In order to aid in the discrimination between true planets and false positives, planet models are fitted and a suite of automated tests is performed on all planet candidate time series data. The iterative model fitting and transiting planet search is capable of identifying multiple planet candidates per solar system. Results for each planetary system are written to a comprehensive document, called the Data Validation (DV) Report. The DV Report presents a summary of the primary findings, detailed model fit and test results based upon prior stellar parameters, and a variety of diagnostic figures. The transition from a 3.5-year baseline to an extended *Kepler* mission will occur in October 2012. DV Reports for current and new planet candidates identified in the Pipeline during the extended mission will be distributed to the science community and the public at large through the Exoplanet Archive (http://exoplanetarchive.ipac.caltech.edu) hosted by the NASA Exoplanet Science Institute (NExScI). We present an overview of the DV Report with the purpose of informing future users about the wealth of information that will soon be available to them for vetting planet candidates identified in the *Kepler* Pipeline. Specific examples are highlighted that demonstrate the utility of the DV Report for distinguishing between valid planet candidates and astrophysical false positives. Funding for the *Kepler Mission* has been provided by the NASA Science Mission Directorate.

330.06 – **Predicting the Potential Planet Yield from Kepler**

Douglas A. Caldwell[1], E. W. Dunham[2], V. S. Argabright[3], W. J. Borucki[4], C. J. Burke[1], J. L. Christiansen[1], R. L. Gilliland[5], J. M. Jenkins[1], J. F. Rowe[1], S. Seader[1], P. Tenenbaum[1], J. Van Cleve[1]

[1]*SETI Institute,* [2]*Lowell Observatory,* [3]*Ball Aerospace and Technologies Corp,*

[4]*NASA Ames,* [5]*STScI.*
9:00 AM - 6:30 PM

The pre-eminent scientific goal of the *Kepler Mission* is to determine the frequency of Earth-size and larger planets in or near the habitable zone of their stars. Two related key requirements needed to support this fundamental goal are the combined photometric precision for target stars and the mission lifetime. *Kepler* was designed to achieve a combined photometric precision -including intrinsic stellar variability- of 20 parts per million in 6.5 hours for 12th magnitude stars and to have a mission lifetime of 3.5 years. Based on the first 2 ½ years of data collection, we find that *Kepler's* precision for these stars is nearer to 30 ppm. We used the measured precision for each target to predict the detectability of habitable zone terrestrial planets based on the pipeline detection threshold of 7.1σ, the mission duration, and the measured data completeness. Combining this with the transit alignment probability and summing over all targets gives the potential planet yield for such planets. We find that the absolute value of the planet yield depends strongly on how biases in the Kepler Input Catalog values of surface gravity and effective temperature are handled, but that the relative improvement in planet yield is a factor of 2.5 to 3 in going from a 3.5 to a 7.5 year mission, largely independent of the KIC biases. Increasing the mission duration to 7.5 years makes up for the factor of ~1.5 increase in noise, restoring *Kepler's* ability to meet its primary mission goal.

331 – Circumstellar Disks

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

331.01 – **Spatially Resolved Millimeter-Wavelength Imaging of Debris Disks**

A. Meredith Hughes[1]

[1]*UC Berkeley.*

9:00 AM - 6:30 PM

Debris disks provide signposts of planet formation in extrasolar systems, and millimeter-wavelength observations probe emission from large dust grains that trace the location of planetesimal belts. We present spatially resolved observations from several millimeter-wavelength facilities (the Submillimeter Array, the Combined Array for Research in Millimeter-wave Astronomy, and the Green Bank Telescope) that provide insight into the structure of planetesimal belts around nearby main sequence stars. Observations of the Vega debris disk support recent data that refute previous observations of clumpy structure, instead indicating that the disk is predominantly smooth and axisymmetric at millimeter wavelengths. Observations of nearby Solar-type stars from the Formation and Evolution of Planetary Systems (FEPS) Spitzer legacy survey reveal the diversity of structures around young Solar analogues. Spatially resolved observations of the unique gas-rich debris disk around HD 141569 reveal a central cavity in the molecular gas emission; we discuss the implications for the formation and evolution of solar systems around nearby stars.

331.02 – **Probing for Exoplanets Hiding in Dusty Debris Disks II: Disk Imaging, Characterization, and Exploration with HST/STIS Multi-Roll Coronagraphy - Update**

Glenn Schneider[1], J. Carson[2], J. Debes[3], M. Goto[4], C. Grady[5], T. Henning[4], D. Hines[3], P. Hinz[1], H. Jang-Condell[6], M. Kuchner[7], A. Moro-Martin[8], P. Marshall[3], G. Serabyn[9], M. Silverstone[10], C. Stark[11], M. Tamura[12], A. Weinberger[11], J. Wisniewski[13], B. Woodgate[7]

[1]*Univ. of Arizona,* [2]*College of Charleston,* [3]*STScI,* [4]*MPIA, Germany,* [5]*Eureka Scientific,* [6]*Univ. Wyoming,* [7]*NASA/GSFC,* [8]*CSIC-INTA, Spain,* [9]*JPL/Caltech,* [10]*Univ. Alabama,* [11]*CIW,* [12]*NOAJ, Japan,* [13]*U. Washington.*

9:00 AM - 6:30 PM

We present new imaging results from a well-selected sample of 11 circumstellar debris disks, all with HST pedigree, using STIS visible-light PSF-subtracted multi-roll coronagraphy. These new observations probe the interior regions of these debris systems, with inner working distances < app 8 AU for half the stars in this sample, corresponding to the giant planet and Kuiper belt regions within our own solar system. These new images enable direct inter-comparison of the architectures of these exoplanetary debris systems in the context of our own Solar System. These observations also permit us, for the first time, to characterize material in these regions at high spatial resolution and identify disk sub-structures that are signposts of planet formation and evolution; in particular, asymmetries and non-uniform debris structures that signal the presence of co-orbiting perturbing planets. As an interim status report for HST/GO12228 still in execution, here we focus on HD61005, PDS66 (a singularly "mature" transition disk in our sample), and (possibly) HD32297. All of our objects were observed previously in the near-IR with inferior spatial resolution and imaging efficacy, but with NICMOS r=0.3 arcsec IWA comparable to STIS multi-roll coronagraphy. The combination of new optical and existing near-IR imaging can strongly constrain the dust properties, thus enabling an assessment of grain processing and planetesimal populations. These results will directly inform upon the posited planet formation mechanisms that occur after the ~ 10 My epoch of gas depletion, a time in our solar system when giant planets were migrating and terrestrial planets were forming, and directly test theoretical models of these processes. These observations uniquely probe into the interior regions of these systems for the first time with spatial resolution comparable to ACS and with augmenting NICMOS near-IR disk photometry in hand. We acknowledge support from STScI for this program (GO12228) and its observations.

331.03 – **Using Gyrochronology to Understand the Evolution of Debris Disks**

Laura Vican[1]

[1]*UCLA.*

9:00 AM - 6:30 PM

Age is one of the most fundamental parameters of a star. Unfortunately, it is also one of the most difficult to measure. A new method for age determination called "gyrochronology" has been developing in the past 5 years. It uses a star's rotation period as a tracer for age. Several surveys have measured rotation periods using variations in Ca II H & K emission cores. We used these measurements to calculate ages for stars in the Herschel/DEBRIS survey. DEBRIS (Disk Emission via a Bias-free Reconnaissance in the Infrared/Submillimeter) is an unbiased survey that searches for debris disks in nearby stars (spectral types A-M). DEBRIS observed a total of 274 F, G, and K-type stars. We were able to use gyrochronology to determine ages for 35 of these stars (other methods were used to calculate ages for a total of 263 F, G, and K-type stars). We are currently extending our study of stellar ages to include stars observed by WISE (Wide-Field Infrared Survey Explorer). By calculating ages for stars with observed IR excesses, we will be able to study the evolution of dusty debris disks over time. This research is made possible by a NASA grant to UCLA.

331.04 – **Carbon Monoxide Absorption in T Tauri Disks**

Matthew McJunkin[1], K. France[2], E. Burgh[2]

[1]*University of Colorado at Boulder,* [2]*CASA-ARL.*

9:00 AM - 6:30 PM

Carbon monoxide (CO) is the most commonly used tracer of molecular hydrogen (H2) in interstellar and circumstellar media. However, the ratio of CO-to-H2 (CO/H2) is poorly constrained in protoplanetary disks. Recent results based on ultraviolet spectra have suggested that the CO/H2 ratio is of order unity, several orders of magnitude larger than the canonical interstellar value of 10^-4. We present new observations from the Hubble Space Telescope and modeling results for CO absorption seen on the sightline to six T Tauri stars. Our modeling allows us to measure the column density, rotational temperature, and Doppler b-value for the molecular disk gas. The high-sensitivity, low instrumental background, and moderate spectral resolution of HST-COS allow us to measure these CO features for the first time. Our absorption line technique requires neither assumption about the geometry not the photo-exciting emission source, in contrast to CO and H2 emission line studies in the far-ultraviolet. Therefore, our absorption line measurements offer a more direct measure of the CO column densities. These results, in combination with future work on H2 absorption lines in these systems, will reveal whether the CO/H2 abundance ratio in protoplanetary disks is truly anomalously high, or if existing observations have missed a large population of cooler H2.

331.05 – **Chemical Kinetics of Polycyclic Aromatic Hydrocarbons in Protoplanetary Disks**

Monika Kress[1], T. Tran[1], J. Chiar[2], A. G. G. M. Tielens[3]

[1]*San Jose State Univ.,* [2]*SETI Institute,* [3]*Leiden Observatory, Netherlands.*

9:00 AM - 6:30 PM

Polycyclic aromatic hydrocarbons (PAHs) comprise about 10% of the carbon in the interstellar medium. There is evidence of modification of PAHs in protoplanetary disks. What happens to these molecules as they are incorporated into protoplanetary disks? We address this question by investigating the chemical kinetics of PAHs in the disk environment. Kress et al. (2010) investigated the chemical behavior of PAHs at temperatures from 1000 to 2000 K at a pressure of 1e-6 bar, and proposed the concept of the 'soot line', analogous to the 'snow line' in the solar nebula. Inside of the soot line, PAHs are irreversibly destroyed via thermally-driven reactions. We will extend this study to more realistic disk conditions and timescales. In a related project (see poster by Tran, Chiar, et al.), we are investigating the differences in the PAH physical characteristics in quiescent dense clouds versus the environment around embedded protostars. Together, these studies will help us understand (1) the fate of interstellar PAHs in planet-forming disks and (2) the relationship between interstellar and solar system PAHs. We also will investigate the soot line in disks around sub-solar mass stars (e.g. M dwarfs). This work has been supported by the NASA Astrobiology Institute's Virtual Planetary Laboratory (PI: V. Meadows) and the NASA/EPOESS program (PI: C. Phillips).

332 – Large Scale Structure, Cosmic Distance Scale

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

332.01 – **Surface Brightness Fluctuation PSF Fitting Techniques with Natural Guide Star Adaptive Optics**

Joseph B. Jensen[1]

[1]*Utah Valley University.*

9:00 AM - 6:30 PM

Getting the most out of natural guide star adaptive optics (AO) observations often requires accurate measurement of the spatially and temporally-varying point spread function (PSF). We have explored some alternatives to the standard PSF measurement strategies and apply them to the Surface Brightness Fluctuation

(SBF) method for measuring extragalactic distances. Model PSFs are compared to empirical PSF measurements made in isolated stars and crowded fields, and we demonstrate how AO images of crowded fields like globular clusters or elliptical galaxies can be used to recover the PSF in Fourier space for arbitrary positions relative to the natural guide star.

332.02 – **Calibrating the IR Surface Brightness Fluctuation Distance Scale Using HST WFC3**

Brigham S. French[1], J. B. Jensen[1], J. P. Blakeslee[2]
[1]*Utah Valley University,* [2]*Dominion Astrophysical Observatory, Canada.*
9:00 AM - 6:30 PM

We have calculated surface brightness fluctuation (SBF) magnitudes for 16 early-type galaxies in the Fornax and Virgo clusters using the F110W (J-band) and F160W (H-band) filters of the Wide Field Camera 3 (WFC3/IR). SBF is a method for determining galaxy distances, and fluctuations in the near-IR are ten times brighter than at optical wavelengths making them measurable in much more distant galaxies. We calibrated the absolute fluctuation magnitude as a function of galaxy color and compared the results using different image processing techniques. This calibration enables SBF distance measurements out to 150 Mpc using the Hubble Space Telescope WFC3/IR, and reveals stellar population differences in the target galaxies.

332.03 – **Characterization Of The Distribution Of The Lyα Emitters In The 53W002 Field At z = 2.4**

Ken Mawatari[1], T. Yamada[1], T. Hayashino[1], Y. Matsuda[2], Y. Nakamura[1]
[1]*Tohoku University, Japan,* [2]*Caltech.*
9:00 AM - 6:30 PM

We present the results of the wide-field (31' x 24') narrow band (custom-made *NB413*) imaging of the field around the radio galaxy 53W002 (the 53W002 field) with Subaru/Suprime-Cam. We detected the 204 Ly-alpha emitters (LAEs) at z = 2.4 down to 26 AB mag (*NB413*) with the rest-frame equivalent width (EW_0) larger than 25 angstrom. We also detected the 4 Ly-alpha blobs (LABs). We identify the significant high density region (53W002F-HDR) that spreads over ~ 5' x 4' and have the LAE number density of nearly four times as dense as the average of the entire field, while only a fraction of the objects detected by the previous medium-band survey was proved to be at z = 2.4. Using the probability distribution function (PDF) of mass fluctuation we evaluate its rareness probability, and find that 53W002F-HDR is the moderately rich structure with the rareness probability of 0.9 %. The distributions of the Ly-alpha *EW* and luminosity in the 53W002 field show no notable environmental dependency at the scale of 10 Mpc, which is also confirmed by using the data of the other fields. By contrast, the four LABs are all found to be located in the rims of high density regions.

This work is supported by the Brain Circulation Program (R2301) by Japan Society for the Promotion of Science.

332.04 – **The Halo Occupation of SDSS Quasars**

Jonathan Richardson[1], Z. Zheng[2], S. Chatterjee[3], D. Nagai[3], Y. Shen[4]
[1]*University of Chicago,* [2]*University of Utah,* [3]*Yale University,* [4]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

We present an estimate of the projected two-point correlation function (2PCF) of quasars in the Sloan Digital Sky Survey (SDSS) over the full range of one- and two-halo scales, 0.02−120 Mpc/h. This was achieved by combining data from SDSS DR7 for the large-scale clustering and Hennawi et al. (2006) (with appropriate statistical corrections) for the small-scale clustering. Our combined clustering sample is the largest spectroscopic quasar clustering sample to date, containing ~48,000 quasars in the redshift range 0.4<z<2.5 with median redshift 1.4. We interpret these precise 2PCF measurements within the halo occupation distribution (HOD) framework and constrain the occupation functions of central and satellite quasars in dark matter halos. From HOD modeling, a small fraction of z~1.4 quasars, (7.4±1.4)×10^(−4), are found to be satellites in dark matter halos, in order to explain the small-scale clustering. At z~1.4, the median masses of the host halos of central and satellite quasars are constrained to be Mcen=(4.1+0.3/−0.4)×10^12 M⊙/h and Msat=(3.6+0.8/−1.0)×10^14 M⊙/h, respectively. To investigate the redshift evolution of the quasar-halo relationship, we also perform HOD modeling of the projected 2PCF measured by Shen et al. (2007) for SDSS quasars with median redshift 3.2. We find tentative evidence for an increase in the mass scale of quasar host halos---the inferred median mass of halos hosting central quasars at z~3.2 is Mcen=(14.1+5.8/−6.9)×10^12 M⊙/h. The cutoff profiles of the mean occupation functions of central quasars reveal that quasar luminosity is more tightly correlated with halo mass at higher redshifts. The average quasar duty cycle around the median host halo mass is inferred to be fq=(7.3+0.6/−1.5)×10^(−4) at z~1.4 and fq=(8.6+20.4/−7.2)×10^(−2) at z~3.2.

332.05 – **Arecibo Observatory Hi Survey Of Extragalactic Sources From Glimpse And Mips Data In The Zone Of Avoidance**

Carmen Pantoja[1], M. Lebron[1], A. Noriega-Crespo[2]
[1]*Univ. of Puerto Rico,* [2]*IPAC/Caltech.*
9:00 AM - 6:30 PM

We report the discovery of 6 new HI galaxies in the zone of avoidance (ZoA). A sample of 25 extremely low Galactic latitude Infrared galaxies located in the Sagitta-Aquila region (Marleau et al. 2008) were observed with the Arecibo Telescope. The velocity of the 6 new Arecibo HI sources range from 5,700 km/s to 10,900 km/s (0.019 > z > 0.037) and none of them have optical counterparts. The HI redshifts for these objects suggest a network of voids for the large scale structure toward the Galactic plane. Marleau, et al. 2008 demonstrated the feasibility of discovering galaxies in the ZoA using mid to far infrared data and this survey shows that infrared sources are very good targets for HI studies of the ZoA.

This project is being used to develop research skills of undergraduate STEM students at the University of Puerto Rico. These HI observations are the initial part of a long term project with undergraduate minority students of the University of Puerto Rico to search for galaxies in the infrared using archived data from GLIMPSE I, II and 3D, and MIPS.

332.06 – **Measuring the Hubble Flow Hubble Constant with Cepheids in the Coma Cluster**

Michael Gregg[1], K. Cook[2], L. Macri[3], D. Welch[4], P. Stetson[5], J. Mould[6]
[1]*University of California,* [2]*Eureka Scientific,* [3]*Texas A&M,* [4]*McMaster U., Canada,* [5]*Herzberg Institute of Astrophysics, Canada,* [6]*Swinburne University, Australia.*
9:00 AM - 6:30 PM

During Hubble Space Telescope Cycle 19, we have gathered 12 epochs of deep imaging with WFC3 of the largest spiral galaxy in the core of the Coma cluster, NGC4921. The goal is to detect and phase classical Cepheid variables to apply this traditional primary distance indicator well out into a region of the Universe where the pure Hubble flow dominates over peculiar velocities, while also leapfrogging over the need for secondary calibration techniques. This tests distance scale results determined locally, and independently derives the Hubble constant for use in constraining cosmological models involving the equation of state of dark energy. We present a progress report towards our main goal. In addition, we also discuss the results of several spin-off science projects enabled by the deep WFC3 imaging. These HST images reveal the spectacular effects of ram pressure stripping on Coma cluster spirals. The images allow characterization of the complete globular cluster population in several Coma galaxies, as well as the intergalactic globular population. Both spin-off results provide insights into the evolution of galaxies in this rich cluster environment.

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333 – Variable Stars and Star Formation

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

333.01 – **Searching for Variable Stars in Southern Globular Clusters**

Brian W. Murphy[1], A. N. Darragh[1], K. E. Conroy[2], E. W. Johnson[1], Z. J. Liu[1], J. M. Toddy[3]
[1]*Butler University,* [2]*Villanova University,* [3]*University of Georgia.*
9:00 AM - 6:30 PM

We present the results of an ongoing study to search for variable stars in southern globular star clusters. The clusters observed thus far include NGC 4833, M14 (NGC 6402), and NGC 6584. The clusters have been observed over the last two years using the Southeastern Association for Research in Astronomy 0.6 meter telescope located at Cerro Tololo Interamerican Observatory. After processing the images, we used the image subtraction package ISIS 2.2 developed by Alard (2000) to search for and identify variable stars. In total we have identified, classified, and produced detailed light curves of 229 variables with 108 of them being newly discovered. Of the total we have identified 111 RRab, 79 RRc, 3 RRe, 7 SX Phoenicis, 7 eclipsing, and 22 long period variables. From the ratio of the numbers of RRab to RRc and average periods of these variables we have classified NGC 6584 as an Oosterhoff Type I and NGC 4833 as an Oosterhoff Type II cluster. Here we present the phased-light curves, periods, V magnitudes, V amplitudes, and classifications along with Bailey diagrams of each clusters and the location of the variables on each of the cluster’s color-magnitude diagrams.

333.02 – **Ten Years Long Near-infrared Variable Star Survey In The Magellanic Clouds**

Yoshifusa Ita[1]
[1]*Tohoku University, Japan.*
9:00 AM - 6:30 PM

We started the near-infrared variable star survey in the Large and Small Magellanic Clouds in December 2000. Since then, we keep monitoring an area of 3 square degrees along the bar in the LMC, and also an area of 1 square degree in the central part of the SMC until the end of 2010. In the 10 years, we observed these areas about 80-90 and 100-110 times for LMC and SMC, respectively. Our survey is the world's first and the only one that provides near-infrared time-series data with such a long baseline and of such a large scale. We will show some preliminary results from the survey in the poster.

This work is supported by the Grant-in-Aid for Encouragement of Young Scientists (B) No.21740142 from the Ministry of Education, Culture, Sports, Science and Technology of Japan. This work is also supported by the Brain Circulation Program (R2301) by Japan Society for the Promotion of Science.

333.03 – **Time-Dependent Behavior of the O'Connell Effect in Eclipsing Binary Star Systems**

Matthew M. Beaky[1], V. Koju[2]
[1]*Juniata College,* [2]*Truman State University.*
9:00 AM - 6:30 PM

The characteristic shape of an eclipsing binary light curve consists of two out-of-eclipse maxima and two mid-eclipse minima. Many eclipsing binary light

curves exhibit unequally high maxima, a feature known as the O'Connell effect. So far, this asymmetry has not been convincingly explained aside from a few individual systems. Most theories attribute the O'Connell effect to phenomena such as starspots, clouds of circumstellar gas and dust, or a hot spot caused by the impact of a mass-transferring gas stream. The high precision and nearly continuous temporal coverage of light curves produced by the Kepler Space Mission make it possible to detect variations in the O'Connell effect within individual systems that have not previously been observed via ground-based observations. Our analysis of Kepler light curves of eclipsing binary systems reveals that in most cases the size and even the sign of the O'Connell effect changes significantly over time scales of weeks or months. Moreover, the magnitude difference between the eclipse minima also varies, usually lagging behind the variations in the difference between the out-of-eclipse maxima by several orbital cycles. We have created models of eclipsing binary systems using Binary Maker 3 that include starspots that migrate slowly in longitude, and have analyze the light curves generated by these model systems. Models with constant starspots at fixed latitude and models with starspots that vary in size and latitude both reproduce the qualitative behavior of the time-dependent O'Connell effect in the Kepler light curves very closely. These results provide support for the notion that the O'Connell effect, at least in some cases, is caused by migrating starspots on the surface of one or both components of the binary star system.

333.04 – **High Precision Cepheid Distances: a 2% Solution for the Calibrating Cepheid SU Cassiopeiae**

David G. Turner[1], D. J. Majaess[1], D. J. Lane[1], D. D. Balam[2], W. P. Gieren[3], J. Storm[4], D. W. Forbes[5], R. J. Havlen[6], B. S. Alessi[7]

[1]Saint Mary's Univ., Canada, [2]Dominion Astrophysical Observatory, Canada, [3]Universidad de Concepcion, Chile, [4]Leibniz-Institut fur Astrophysik Potsdam (AIP), Germany, [5]Sir Wilfred Grenfell College, Canada, [6]307 Big Horn Ridge, NE, [7]Universidade de Sao Paulo, Brazil.

9:00 AM - 6:30 PM

The distance to the 1.95-day Cepheid SU Cas has been reevaluated using its membership in the newly-discovered cluster Alessi 95, its pulsation parallax, Hipparcos parallaxes for 18 cluster stars, and a main-sequence fit in JHK for GKM-type stars, yielding d = 429 +-8 pc, 414 +-12 pc, 420 +-33 pc, and 410 +-15 pc, respectively, values coincident within their uncertainties and implying a precision of at most a few percent. Systematic effects may exist in each methodology, for example, the zero-point calibration and metallicity corrections in ZAMS fitting, the projection factor for applications of the Baade-Wesselink method, and questions about Hipparcos absolute parallaxes, yet such excellent consensus in distance is not evident for other Galactic Cepheid calibrators. The inferred distance implies overtone pulsation for SU Cas, as also argued by the Fourier parameters for its light curve and its rate of period increase, with an equivalent period for fundamental mode pulsation of 2.75-days. A newly-derived field reddening of E(B-V) = 0.33 +-0.02 for SU Cas yields an absolute magnitude of <Mv> = -3.15 +-0.07 for the Cepheid, slightly more luminous than expected for a Cepheid lying on the blue edge of the instability strip.

333.05 – **On The Pulsation Modes And Masses Of Osarg Variables**

Masaki Takayama[1], H. Saio[1], Y. Ita[1]

[1]Tohoku University, Japan.

9:00 AM - 6:30 PM

OSARG(OGLE Small Amplitude Red Giants) are red giant (RGB/AGB) variables found in LMC/SMC and our Galactic bulge. By comparing the period-luminosity relations of LMC OSARG with calculated pulsation periods, we have found that various pulsation modes should be excited in OSARG; radial 1st, 2nd and 3rd overtone, and non-radial p1, p2 and p3 modes of l=2. In addition, we have found that the masses of RGB OSARG are in a range of 0.9 <= M/Msun < =1.4, while AGB OSARG have masses between 1 and 2.5 M/Msun. The AGB OSARG are still in early AGB stages and would be progenitors of Mira/Semi-regular variables.

This work is supported by the Brain Circulation Program (R2301) by Japan Society for the Promotion of Science.

333.06 – **A Significant Population of Candidate New Members of the Rho Ophiuchi Cluster**

Karl E. Haisch[1], M. Barsony[2], K. A. Marsh[3], C. McCarthy[4]

[1]Utah Valley University, [2]SETI Institute, [3]IPAC, Caltech, [4]San Francisco State University.

9:00 AM - 6:30 PM

We present a general method for identifying the pre-main-sequence population of any star-forming region, unbiased with respect to the presence or absence of disks. We have applied this technique to a new, deep, wide-field, near-infrared imaging survey of the Rho Ophiuchi cloud core to search for candidate low mass members. In conjunction with published Spitzer IRAC photometry, and least squares fits of model spectra (COND, DUSTY, NextGen, and blackbody) to the observed spectral energy distributions, we have identified 948 candidate cloud members. This population represents a factor of almost 3 increase in the number of known young stellar objects in the Rho Ophiuchi cloud. A large fraction (81% +/- 3%) of the candidate cluster members exhibit infrared excess emission consistent with the presence of disks, thus strengthening the possibility of their being bona fide cloud members.

333.07 – **Recent Star Formation in the Galaxy and Magellanic Clouds**

Guido De Marchi[1], N. Panagia[2], G. Beccari[3], M. Romaniello[3], E. Sabbi[2], L. Spezzi[3]

[1]ESA, Netherlands, [2]STScI, [3]ESO, Germany.

9:00 AM - 6:30 PM

Using the Hubble Space Telescope, we have undertaken a systematic study of pre-main-sequence (PMS) stars spanning a wide range of masses (0.5 - 4 M_{sun}), metallicities (0.1 - 1 Z_{sun}) and ages (0.5 - 30 Myr). These PMS objects are located in very different environments in the Milky Way and Magellanic Clouds. Thanks to a novel method that we have developed to combine broad-band (V,I) photometry with narrow-band Halpha imaging, we have determined the physical parameters (temperature, luminosity, age, mass and mass accretion rate) of more than 3000 bona-fide PMS stars still undergoing active mass accretion. This is presently the largest and most homogeneous sample of PMS objects with known physical properties and it includes not only very young objects, but also PMS stars older than 10-20 Myr that are approaching the main sequence. We present here some of the main results of this research, including the fact that mass accretion rate appears to scale with the first power of the stellar mass, with the square root of the age, and approximately with the inverse of metallicity.

333.08 – **Observational Diagnostics of Massive Stellar Evolution**

Remy Indebetouw[1], K. Wood[2], B. A. Whitney[3]

[1]Univ. of Virginia and NRAO, [2]Univ. of St Andrews, United Kingdom, [3]Univ. of Wisconsin.

9:00 AM - 6:30 PM

Massive young stellar objects (MYSOs) are identified using a diverse set of observational tracers, from masers to centimeter emission to mid-infrared ice absorption. Fairly simple assumptions are usually used to try to gauge MYSO evolutionary state; e.g. that ionizing radiation is quenched by a heavily accreting protostar, so that the youngest luminous sources should not have a detectable H+ region. We present self-consistent sets of models for protostars accreting from less than 1 to 100 solar masses, predicting the ionized gas emission (centimeter free-free continuum and infrared fine-structure lines), the dust spectral energy distribution, and the PAH emission along each evolutionary track. These can be compared with large samples of MSYOs in the Milky Way and Magellanic System for which we now have multi-tracer datasets.

333.09 – **A Systematic Search for Molecule Outflows Toward Candiate Low-Luminosity Protostars**

Kamber R. Schwarz[1], Y. L. Shirley[1], M. M. Dunham[2]

[1]University of Arizona, [2]Yale University.

9:00 AM - 6:30 PM

We present a systematic search for molecular outflows toward a sample of 39 candidate low-luminosity protostars in ^{12}CO and ^{13}CO 2-1 using the 10 meter Heinrich Hertz Telescope at 30'' resolution. The sample of sources is drawn from the catalog of Dunham et al. of candidate low-luminosity protostars and VeLLOs in observed by the Spitzer Space Telescope in nearby molecular clouds. We present maps of the previously known outflow L673-7 and L1251-A IRS4 with more sensitivity than previously available and analyze their properties. Potential outflow candidates were identified in the dense cores B59, L1148, L1228, and L1165 based on the presence of line wings. Of these, only one source, in B59, shows a distinct blue outflow lobe in the mapped emission. The remaining sources do not show clear evidence for outflows at our resolution. Partial Funding for KRS was provided by the Arizona Space Grant Consortium. YSL is partially supported by NSF grant AST-1008577.

333.1 – **A Complete Spectroscopic Survey of Dense Molecular Gas in Clumps in the Bolocam Galactic Plane Survey with $l geq 7.5$ deg**

Yancy L. Shirley[1], T. Ellsworth-Bowers[2], S. Mairs[3], E. Rosolowsky[3], A. Ginsburg[2], C. Battersby[2], G. Stringfellow[2], M. Dunham[4], W. Schlingman[1]

[1]Univ. of Arizona, [2]Univ. of Colorado, [3]UBC, Canada, [4]Yale.

9:00 AM - 6:30 PM

We present a complete spectroscopic survey of dense molecular gas in 6207 clumps identified in the Bolocam Galactic Plane Survey (BGPS) with galactic longitude geq 7.5 deg. The clumps were observed simultaneously in the tracers HCO$^+$ and N$_2$H$^+$ 3-2 using the ALMA Band 6 proto-type receiver on the Heinrich Hertz Submillimeter Telescope. These observations provide the velocities needed to derive kinematic distances to clumps in the BGPS, ATLASGAL, and HIGAL continuum galactic plane surveys. Dense molecular gas is detected in over 50% of clumps in the BGPS catalog. We present a direct comparison of the HCO$^+$ and N$_2$H$^+$ emission properties with the 1.1 millimeter continuum and with a subset of cores observed in NH$_3$ (1,1) and (2,2) with beam matched resolution ($30^{primeprime}$) . The full spectroscopic catalog is publicly available at http://eldora.as.arizona.edu/~yshirley/Arizona/BGPS/

333.11 – **Formaldehyde Densitometry Of Galactic Star-Forming Regions Using The H2CO 3(12)-3(13) And 4(13)-4(14) Transitions**

Patrick McCauley[1], J. G. Mangum[2], A. Wootten[2]

[1]Smithsonian Astrophysical Observatory, [2]National Radio Astronomy Observatory.

9:00 AM - 6:30 PM

We present Green Bank Telescope observations of the 3_{12}-3_{13} (29 GHz) and 4_{13}-4_{14} (48 GHz) transitions of the H_2CO molecule toward a sample of 23 well-studied star-forming regions. Analysis of the relative intensities of these transitions can be used to reliably measure the densities of molecular cores. Adopting kinetic temperatures from the literature, we have employed a large velocity gradient (LVG) model to derive the average hydrogen number density [$n(H_2)$] within a 16'' beam toward each source. Densities in the range of

$10^{5.5}$-$10^{6.5}$ cm^{-3} and ortho-formaldehyde column densities per unit line width between $10^{13.5}$ and $10^{14.5}$ cm^{-2} $(km\ s^{-1})^{-1}$ are found for most objects, in general agreement with existing measurements. A detailed analysis of the advantages and limitations to this densitometry technique is also presented. We find that H_2CO 3_{12}-3_{13}/4_{13}-4_{14} densitometry proves to be best suited to objects with T_K >~ 100 K, above which the H_2CO LVG models become relatively independent of kinetic temperature. This study represents the first detection of these H_2CO *K*-doublet transitions in all but one object in our sample. The ease with which these transitions were detected, coupled with their unique sensitivity to spatial density, makes them excellent monitors of density in molecular clouds for future experiments. We also report the detection of the 9_2-8_1 A^- (29 GHz) transition of CH_3OH toward six sources. This work was funded by the National Science Foundation through the National Radio Astronomy Observatory. Refer to the corresponding ApJ publication (742:58, 2011) for additional information.

333.12 – **The ISM Around Natal Clusters in NGC4490**

Kelsey E. Johnson[1], R. Indebetouw[1], D. G. Whelan[1], A. E. Reines[2]
[1]Univ. of Virginia, [2]NRAO.
9:00 AM - 6:30 PM

Massive star clusters are important agents of galactic evolution in the local universe. In order to better understand the formation and early evolution of these clusters, it is necessary to determine the physical conditions in their natal environments. Here we present radio and infrared observations of a set of natal clusters in the galaxy NGC4490. We identify a number of radio sources in this galaxy that are dominated by thermal emission, which is a strong indicator of extreme youth (< a few Myr). These sources are also the dominant 24 micron emitters in the galaxy. Four of the these sources have corresponding Spitzer spectroscopy, which is used to determine the excitation and densities of their ionized gas. These combined data indicate a rough evolutionary sequence among the four sources. The youngest and most extreme source "B" has properties similar to 30 Doradus at an earlier stage of its evolution, while the oldest source in the sequence has dispersed more of its natal envelope.

333.13 – **The Impact Of Turbulence On The Physical State Of The Molecular Gas And On Star Formation In Galaxy Interactions: The Case Of Stephan's Quintet**

Pierre Guillard[1], F. Boulanger[2], P. Appleton[3], E. Falgarone[4], A. Gusdorf[4], U. Lisenfeld[5], P. Duc[6]
[1]Caltech, [2]Institut d'astrophysique Spatiale, France, [3]Nasa Herschel Science Center, IPAC, Caltech, [4]ENS, LERMA, France, [5]Instituto de Astrofisica de Andalucia, CSIC, Spain, [6]AIM, CEA, France.
9:00 AM - 6:30 PM

Spitzer spectroscopy has revealed a significant and diverse population of extragalactic sources where the mid-infrared rotational line emission of warm (> 150 K) molecular hydrogen (H2) is strongly enhanced, while star formation seems suppressed. This poster focuses on the Stephan's Quintet (SQ) compact group of galaxies, a template source to study the impact of galaxies interaction on the physical state and energetics of their gas. SQ is a spectacular example of these powerful H2 emitters, where we can spatially separate molecular gas formed in the shock from that associated with star-forming regions. I will present CO line observations obtained with the IRAM 30m and interferometer, showing that the collision has triggered the formation of highly turbulent, unbound giant molecular complexes. The ratio between the warm H2 mass and the H2 mass derived from CO fluxes is 0.3, which is 10-100 times higher than in star-forming galaxies. I will discuss a model for molecular gas formation and heating by the dissipation of turbulent kinetic energy. This interpretation implies that the velocity dispersion on the scale of giant molecular clouds in SQ is an order of magnitude larger than the Galactic value. This may explain why this gas is not forming stars efficiently. This study has important consequences on our understanding of the regulation of star formation and galaxy building in a broader population of sources experiencing strong input of kinetic energy in their interstellar medium.

333.14 – **The Role of Irradiated and Shocked Cavity Walls on Observations of Protostellar Regions**

Steven D. Doty[1], S. Bruderer[2], L. Kristensen[3], R. Visser[4], E. van Dishoeck[3], C. Crocker[1]
[1]Denison Univ., [2]Max Planck Institute for Extraterrestrial Physics, Germany, [3]Sterrewacht Leiden, Netherlands, [4]University of Michigan.
9:00 AM - 6:30 PM

Recent observations of protostellar regions by the Herschel Space Observatory show significant emission from highly excited CO and other molecules. The strength of this emission is difficult to understand in the context of a spherical protostellar envelope. Recently, a model for low-mass envelopes has been proposed that focuses on the essential role of an outflow cavity. By its direct line-of-sight to the central source, this allows energy deposition by shocks and UV photons. This model is extended to high-mass star-formation, and compared with observations to probe the relevance of such a model for high-mass regions.

333.15 – **The Effects Of Grain Surface Chemistry In Evolving High-mass Star Forming Regions**

Sandra L. Doty[1], S. Doty[2], R. Visser[3], E. F. van Dishoeck[4]
[1]Ohio University of Lancaster, [2]Denison University, [3]University of Michigan, [4]Sterrewacht Leiden, Netherlands.
9:00 AM - 6:30 PM

Massive star-forming regions are expected to be highly dynamic. Most previous studies of their chemistry have focused on primarily gas-phase processes, and treated this processes in predominantly static envelopes. In this paper, we study the effects of grain surface chemistry, including evolution (infall) from the circumstellar envelope. It is found that both grain-surface chemistry and infall can have meaningful effects. These effects, and their implications for observations, are discussed.

333.16 – **Beads, Knots, and Gems: The Role of Swallowtails and Caustics in Triggering Star Formation in Interacting Galaxies**

Beverly J. Smith[1], M. L. Giroux[1], C. Struck[2]
[1]East Tennessee State Univ., [2]Iowa State University.
9:00 AM - 6:30 PM

Interacting galaxies provide a wide variety of exotic star forming environments that typically are not seen in isolated galaxies. They can exhibit regularly-spaced `beads-on-a-string' knots of star formation along tidal features, very luminous clumps of star formation near the base and ends of tidal features, and gas-rich star-forming structures produced by accretion from one galaxy to another. In a sample of nearby galaxies, we explore these regions at high spatial resolution using archival Hubble Telescope images, and determine the age, luminosity, and spatial distribution of star clusters within these regions. We compare these results with numerical and analytical models of the interactions to better understand star formation triggering within these features. In particular, we investigate the role played by caustics and swallowtails (intersecting caustics) in triggering star formation, where a caustic is a narrow pile-up zone caused by orbit-crowding.

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334 – Young Stellar Objects, Very Young Stars, T-Tauri Stars, H-H Objects

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

334.01 – **SOFIA Follow-up to Spitzer Observations of the North America Nebula**

David M. Cole[1], L. Rebull[2]
[1]IPAC, [2]Spitzer Science Center.
9:00 AM - 6:30 PM

Much of our current knowledge regarding star-forming patterns and circumstellar disk evolution derives from study of molecular cloud complexes within a few hundred parsecs of the Sun, such as Taurus (140 pc) or Orion (400 pc). Studies of these two regions are the primary touchstones that inform our understanding of how stars form. However, the environments of the two regions are different in many ways. Because the environment does matter, for a comprehensive understanding of star formation it is important that we study more than just the nearest examples of the extrema of star formation modes. A good example of "mixed-mode" star formation is the relatively nearby (~520 pc) North America (NGC 7000) and Pelican (IC 5070) Nebulae complex (hereafter NAN). We observed the NAN with Spitzer (3.6 to 160 um), revealing a complex ISM distribution and more than 700,000 point sources. In particular, the "Gulf of Mexico" off "North America" is revealed to be a dramatic cluster of 100s of objects, many seen only at 24 microns. We obtained SOFIA data of the most confused portion of the Gulf cluster, using its higher spatial resolution at 24um to reveal more sources, and the addition of 35um data to better define the spectral energy distributions (SEDs) of several of these young stellar objects (YSOs). This should help us characterize the properties of the many YSOs here and give us insight into some of the youngest objects in the NAN, as well as improve our understanding of the star formation process in dense regions such as this.

334.02 – **Spectro-astrometry Of H2O And OH In A Protoplanetary Disk**

Logan R. Brown[1], E. L. Gibb[1], M. R. Troutman[1]
[1]University of Missouri - St. Louis.
9:00 AM - 6:30 PM

To understand how life originated on Earth, we must investigate how the necessary water and other prebiotic molecules were distributed through the protoplanetary disk from which the solar system formed. To infer this, we study analogs to the early solar system, T Tauri stars, which are surrounded by circumstellar disks. These disks generally have masses on the order of tens of Jupiter masses and extend outward to about 100 AU. These disks have a flared geometry. Of particular interest here is the chemistry of these objects.

Disks have three main chemical regions: the cold midplane, warm molecular layer, and hot ionized region (Walsh et. al. 2010). The cold midplane is a cold, dense region where molecules freeze onto dust grains. In the warm molecular layer above that, molecular synthesis is stimulated by increasing temperatures and the evaporation of molecules from dust grains. Above that, stellar and cosmic radiation dissociates and ionizes molecules into constituent radicals, atoms, and ions in the hot ionized disk atmosphere.

Spitzer Space Telescope observations found a rich water emission spectrum toward T Tauri star AA Tau (Salyk et al. 2008). How this water is distributed through a protoplanetary disk is of particular interest. This can be determined using a technique called spectro-astrometry that measures the spatial dependence of a spectral feature. We present high-resolution, near-infrared spectroscopic data from the T Tauri star DR Tau, obtained on 16 -18 February 2011 using NIRSPEC at the Keck II telescope. We detected both water and OH in emission and report our

spectro-astrometric signals and the derived spatial extent of the gas emission in the disk. Supported by NSF 0908230.

Salyk, C. et al. 2008, ApJ, 676, 49

Walsh, C., Miller, T. J., & Nomura, H. 2010 ApJ, 722, 1607

334.03 – **WISE Photometry of Young Stellar Object Candidates in the Canis Major Star-Forming Region**

Deborah Padgett[1], W. Liu[2], L. Rebull[2], D. Leisawitz[1]

[1]*NASA/Goddard Space Flight Center,* [2]*California Institute of Technology.*
9:00 AM - 6:30 PM

We present WISE (Wide-field Infrared Survey Explorer) photometry of young stellar object candidates in the Canis Major clouds at a distance of 1 kpc. WISE has identified 682 objects with apparent 12 and 22 micron excess emission in a 7 deg x 10 deg field around the the CMa R1 cloud. While a substantial fraction of these candidates are likely galaxies, AGB stars, and artifacts from confusion along the galactic plane, others are part of a spectacular cluster of YSOs imaged by WISE along a dark filament in the R1 cloud. Palomar Double Spectrograph observations of several sources in this cluster confirm their identity as young A and B stars with strong emission lines. In this contribution,we plot the optical - mid-infrared spectral energy distribution for the WISE YSO candidates and discuss potential contaminants to the sample. The data demonstrate the utility of WISE in performing wide-area surveys for young stellar objects.

334.04 – **Infrared Variations in NGC 1333**

Luisa M. Rebull[1], YSOVAR team

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

YSOVAR (Young Stellar Object VARiability) is a Spitzer Space Telescope Cycle 6 Exploration Science Program (PI: J. Stauffer). The Exploration Science programs were defined as large programs during the Warm mission (using the first two channels of IRAC, 3.6 and 4.5 microns). These large programs are in excess of 500 hours of requested observing time. YSOVAR had ~550 hours of time, with the goal of obtaining the first extensive mid-infrared time-series photometry of a dozen star-forming regions. YSOVAR was planned to provide more than 50 epochs of data for more than 2000 young stars, with complementary ground-based data in the optical and near-infrared. This poster will summarize the initial results found in our monitoring of the NGC 1333 region.

334.05 – **X-rays from Jets in Accreting T Tauri Stars**

Steve L. Skinner[1], M. Guedel[2], A. Liebhart[2], M. Audard[3], K. Briggs[2]

[1]*Univ. Of Colorado,* [2]*Univ. of Vienna, Austria,* [3]*Univ. of Geneva, Switzerland.*
9:00 AM - 6:30 PM

Jets in star-forming regions are associated with accreting protostars and classical T Tauri stars (cTTS). Jets regulate accretion by removing angular momentum from the star-disk system and influence star-formation by injecting momentum and turbulence into the surrounding cloud. Jets in young stars have traditionally been studied using optical and radio telescopes which mainly probe cool jet plasma at T < 10,000 K. However, X-ray observations have now detected much hotter jet plasma (T ~ few million K) in the inner regions of cTTS jets within a few arcseconds from the star. The mechanisms by which jet plasma is heated to X-ray emitting temperatures are not yet well understood, but either shocks or magnetic heating could contribute. We will present a summary of recent X-ray observations of accreting cTTS in nearby star-forming regions (primarily Taurus) whose jets are well-traced optically. We will summarize hot jet plasma properties that are inferred from X-ray images and spectra and will discuss possible jet heating mechanisms.

334.06 – **Searching for Prebiotically Important Molecules in Protoplanetary Disks**

Erika L. Gibb[1], L. R. Brown[1], E. Sudholt[1]

[1]*Univ. of Missouri - St. Louis.*
9:00 AM - 6:30 PM

Understanding how prebiotic molecules form and are distributed around young stars is an important step in determining how and where life can form in planetary systems. In general, protoplanetary disks consist of a cold, dense midplane where, beyond the frost line, water and organic molecules will condense onto dust grains as icy coatings. The surface of the disk is exposed to stellar and interstellar radiation, giving rise to a photon-dominated region characterized by ionization and dissociation products. Between these two layers is a warm molecular layer where a rich molecular chemistry is predicted to occur. The warm molecular layer is somewhat protected from ionizing radiation by the dust and polycyclic aromatic hydrocarbons (PAHs) in the surface region.

We present a high-resolution (λ / $\Delta\lambda$ ~ 25,000), near-infrared spectroscopic survey of the L-band toward T Tauri star GV Tau N. The data were acquired with the NIRSPEC instrument on the Keck II telescope, located on Mauna Kea, HI. We detected strong HCN absorption lines that we interpret to be located in the warm molecular layer of a nearly edge-on protoplanetary disk. We discuss significant differences in spectra acquired in 2006 and 2010 and implications for the material in the disk of GV Tau N, including rotational temperatures, abundances, and inferred location.

This work was supported by the NSF Stellar Astronomy Program (Grant #0908230) and the NASA Exobiology program (NNX11AG44G).

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335 – AGN, QSO, Blazars

Poster Session – Exhibit Hall, Dena'ina Center – 6/12/2012 9:00:00 AM to 6/12/2012 6:30:00 PM

335.01 – **Polarimetry as a Probe of the Physical Conditions in the Gamma-ray-flaring Blazar PKS 1510-089**

Margo F. Aller[1], H. D. Aller[1], P. A. Hughes[1], A. P. Marscher[2], S. G. Jorstad[2], T. Hovatta[3], P. S. Smith[4]

[1]*Univ. of Michigan,* [2]*Boston University,* [3]*California Institute of Technology,* [4]*University of Arizona.*
9:00 AM - 6:30 PM

As part of work to localize the Fermi-detected gamma-ray emission from blazars, we present UMRAO centimeter-band monitoring of total flux density and linear polarization, and time- coordinated optical polarimetry, of PKS 1510-089 with emphasis on strong, multi-month gamma-ray flaring commencing in July 2011. We relate the source-integrated radio-band variability to structural changes identified from 43 and 15 GHz VLBA imaging. Peak fluxes include the highest-amplitude flares observed in 1510-089 in 4 decades of UMRAO monitoring (6.6 Jy at 14.5 GHz), and daily-binned gamma-ray fluxes exceeding 1x10^{-5} photons cm^{-2} s^{-1} at 0.1-200 GeV. During these gamma-ray flares, centimeter-band monitoring reveals a time-associated monotonic rise in total flux density from July 2011 to January 2012 with an increase in polarized flux and an unusual superposed 1 Jy mini-flare with a timescale of less than 1 month in January; a sharp increase in the 43 GHz flux occurred in October. Prior intense gamma-ray flaring (2009.0-2009.5) was attributed to inverse Compton scattering of infrared seed photons in a slow moving jet sheath and optical synchrotron emission arising in the faster jet spine (ApJL, 710, L126, 2010). We compare the recent events to the 2009 activity to assess whether the same inner jet features are responsible. Despite the current sustained high amplitude of the total flux density, no circularly polarized emission was detected at the 3-sigma level. An intriguing long-term correspondence between optical and radio band EVPAs is discussed. Funding was provided by NSF grant AST-0607523 and NASA/Fermi GI grants NNX09AU16G, NNX10AP16G, & NNX11AO13G (U. Michigan); NSF grant AST-0907893 and NASA/Fermi GI grants NNX08AV65G and NNX11AQ03G (BU); NSF grant AST-0807860, NASA/Fermi grant NNX08AV67G, and an award from the Jenny and Antti Wihuri foundation (T.H); and NASA/Fermi GI awards NNX08AW56G and NNX09AU10G (P.S.S.).

335.02 – **The Stellar Environments of Supermassive Black Holes in Nearby Seyfert 2 Galaxies**

Alexandra Truebenbach[1], E. C. Moran[1]

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

Correlations between the masses of supermassive black holes and the large-scale properties of their bulge-dominated host galaxies suggest a picture in which galaxy evolution and the growth of black holes are coordinated via galaxy mergers. Two classes of galaxies with active nuclei have the potential to provide useful insights: low-mass dwarf galaxies and massive, bulgeless galaxies. Both contain accreting supermassive black holes, but neither is expected to be the product of a major merger. We have modeled the surface brightness distributions of a small sample of such objects to characterize the stellar environments of their central black holes. First, we present analysis of *Hubble Space Telescope* images of the dwarf galaxy NGC 4117 (M_g = -17.7, $M* = 7 \times 10^9$ $M_\odot$), which, because of its proximity (~ 18 Mpc) and lack of a bright central point source (it is a type 2 Seyfert), complements recent studies of more distant low-mass galaxies with luminous type 1 active nuclei. Second, we have analyzed images from the Sloan Digital Sky Survey of a handful of previously unrecognized Seyfert 2 galaxies that appear to be bulgeless spirals. All are nearby (d = 30-70 Mpc) and luminous ($M_g \approx$ -20). Our results confirm that none of the objects contains a classical bulge. This supports the view that secular processes are responsible for the evolution of both types of galaxies and their current episodes of nuclear activity.

335.03 – **Characterizing the Iron Kalpha Line Equivalent Width in Heavily Obscured AGN**

Laura Trouille[1], R. Hickox[2], D. Alexander[3]

[1]*Northwestern University CIERA Postdoctoral Fellow,* [2]*Dartmouth College,* [3]*Durham University, United Kingdom.*
9:00 AM - 6:30 PM

The fluorescent iron Kalpha emission line in the X-ray spectra of Active Galactic Nuclei (AGN) is thought to arise both from the accretion disk (resulting in the broad line component) and from the 'torus' of obscuring material further out (resulting in the narrow line component). A number of theoretical studies and observational results suggest that the equivalent width of the narrow line component increases with column density. Compton-thick sources, with NH>10^24cm^2, are thought to have iron Kalpha equivalent widths around 1keV or greater. However, there is considerable uncertainty, both in theory and in observation, for the details of the relationship between this equivalent width and column density. In this study we take advantage of the extremely deep Chandra Deep Field South 4Ms image and our STACKFAST stacking program to address this question. We report the trends we observe in equivalent width with column density. We also discuss the contamination rate we find for various Compton-thick AGN selection methods from the literature, using the stacked source iron line equivalent width as our barometer.

335.04 – **Where The Active Galaxies Live: A Panchromatic View Of AGN In**

The Akari-NEP Field

Marios Karouzos[1], M. Im[1], T. Takagi[2], H. Shim[3], J. Ko[4], H. Matsuhara[2], R. Braun[5], G. White[6], S. Serjeant[6]

[1]*CEOU-Seoul National University, Korea, Republic of,* [2]*ISAS-Japanese Aerospace Exploration Agency, Japan,* [3]*Kyung-Pook National University, Korea, Republic of,* [4]*Yonsei University, Korea, Republic of,* [5]*CSIRO-Astronomy and Space Science, Australia,* [6]*The Open University, United Kingdom.*

9:00 AM - 6:30 PM

We study the host galaxy properties of radio-detected sources in the AKARI-NEP field, using an ensemble of multi-wavelength datasets that range from the far-UV to the radio. Using both photometry and spectroscopy, we identify both radio-loud and radio-quiet AGN and study their host galaxy properties, including the age of their stellar populations, current star-formation rates, as well as their morphology. Using this information we investigate the role of AGN within the currently accepted framework of a merger-driven evolution of galaxies.

This research was supported through the Creative Research Initiative program, No. 2010-0000712, of the National Research Foundation of Korea (NRFK) funded by the Korea government(MEST).

335.06 – **Correlation Between Galaxy Mergers and AGN Activity**

Jueun Hong[1]

[1]*Seoul National University, Korea, Republic of.*

9:00 AM - 6:30 PM

Using deep images taken at Maidanak 1.5m telescope, at McDonald 2.1m telescope and Canada-France-Hawaii Telescope, Dupont 2.5m telescope, we investigated the fraction of galaxy mergers in hosts of 39 luminous AGN which are brighter than M = -22 mag and nearer than z = 0.3. We found that 16 to 17 of 39 AGN host galaxies show the evidence of mergers like tidal tail, shell, gravitationally disturbed features via careful visual inspection. We also studied with the merging fraction of a control sample, SDSS Stripe82 early type galaxies of which surface brightness limit and bulge magnitude are similar to that of the AGN sample. Our result is that merging fraction of the AGN sample is higher than that of early type galaxy samples in the whole range of bulge magnitude. This result implies that AGN activity may be correlated with merging. We also investigated the detailed morphology of merging feature. At least 1/4 of control samples having a tidal and tidal+dust feature show shell structures. On the other hand only one (5.9%) of AGN sample classified as merger shows shell structures, and almost all merging AGNs show tidal tail features. From point of view that tidal tail can appear at the early stage of merging, and shell can appear at the late stage of mergers, expected by simulation study, this result suggests that AGN might be evolved into early-type galaxies after merging.

335.07 – **Gamma-ray Bright Narrow Line Seyfert 1s: Their Host Galaxies and Origin**

Timothy S. Hamilton[1], L. Foschini[2]

[1]*Shawnee State Univ.,* [2]*National Institute for Astrophysics—Astronomical Observatory of Brera, Italy.*

9:00 AM - 6:30 PM

In the last few years a new class of radio-loud AGN has emerged: gamma-ray bright Narrow Line Seyfert 1s (g-NLS1). The broader class of NLS1s (characterized by their narrow permitted lines) are usually radio-quiet, have small black holes, high Eddington ratios, and are hosted in spiral galaxies. While a few NLS1s are radio-loud, the evidence for relativistic jets was ambiguous until the discovery of strong gamma-ray emission from five of these. As NLS1s are hosted by spirals, this may break the paradigm that associates relativistic jets with elliptical galaxies.

Of these five, only the nearest one has been imaged at high resolution, and it is the only one whose host galaxy can be seen. We present our analysis of archival HST images of 1H 0312+341. While we clearly see spiral arms, we find no evidence for a separate bulge and disk_in fact, no evidence for a disk at all. The best fit follows a de Vaucouleurs profile, characteristic of elliptical galaxies. Comparing with our studies of quasar hosts, we believe this combination may indicate a recent merger. The structure of 1H 0312+341 may also distinguish it from “normal” NLS1, which have pseudobulges and are fueling by secular processes, rather than mergers.

But 1H 0323+341 may be an unusual g-NLS1. It shows strong disk emission, unlike its cohorts. With so few of these to study, an approach is to image the hosts of the more common radio-loud NLS1s these are drawn from.

335.08 – **Herschel Observations Of A Very Hard X-ray Selected Sample Of Agn In The Local Universe**

Marcio Melendez[1], R. Mushotzky[1], A. Barger[2], L. Cowie[3], W. Baumgartner[4], M. Koss[3]

[1]*University of Maryland,* [2]*University of Wisconsin,* [3]*University of Hawaii,* [4]*NASA/Goddard.*

9:00 AM - 6:30 PM

We present our preliminary results of the analysis of Herschel observations of a very hard X-ray selected AGN sample of the local universe. High column densities of absorbing material along our line of sight can significantly change the observed properties of AGNs. High column densities of absorbing material along our line of sight can significantly change the observed properties of AGNs. Thus, optical, infrared, and soft X-ray selected samples are hampered by extinction, star formation and absorption, respectively. Therefore an unbiased sample of AGNs is important to investigate the "hidden" nature of the nuclear source. The swift BAT survey in the 14-195 keV band represents a complete sample including Compton thin and previously unknown or non-famous AGNs that were missed from previous X-ray surveys in the 2-10 keV band. Our BAT AGN sample contains 350 objects ($z < 0.05$) that have been observed with the Photodetector Array Camera and Spectrometer (PACS) and the Spectral and Photometric Imaging Receiver (SPIRE) on board Herschel (PI: R. Mushotzky). We present our preliminary results of the broadband SED for the BAT sample from 70 to 500 um and corresponding SED modeling. These results will provide a robust understanding of the origins of the FIR emission.

335.09 – **Characterizing Quasar Outflows I: Sample, Spectral Measurements**

Rajib Ganguly[1], D. H. Christenson[1], J. M. Richmond[1], J. A. Derseweh[1], J. M. Robbins[1], S. L. Townsend[1], M. A. Stark[1]

[1]*Univ. of Michigan-Flint.*

9:00 AM - 6:30 PM

Galaxy evolution models have shown that quasars are a crucial ingredient in the evolution of massive galaxies. Outflows play a key role in the story of quasars and their host galaxies, by helping regulate the accretion process, the star-formation rate and mass of the host galaxy (i.e., feedback). The prescription for modeling outflows as a contributor to feedback requires knowledge of the outflow velocity, geometry, and column density. In particular, we need to understand how these depend on physical parameters and how much is determined stochastically (and with what distribution). For this purpose, we are examining a sample of 11000 z=1.7-2.0 quasars from the Sloan Digital Sky Survey. This redshift range permits the following from the SDSS spectra: (1) separation of objects that do and do not exhibit outflows; (2) classification/measurement of outflow properties (ionization, velocity, velocity width); and (3) measurements of UV emission line and continuum parameters. In this poster, we subjectively divide these quasars into four categories: broad absorption-line quasars (2700 objects), associated absorption-line quasars (1700 objects), reddened quasars (160 objects), and unabsorbed/unreddened quasars (6300 objects). We present measurements of the absorption (velocities, velocity widths, equivalent widths), composite spectral profiles of outflows as a function of velocity, as well as measurements of the continuum and CIV, MgII, and FeII emission-line properties. In accompanying posters, we add photometry from the rest-frame X-ray (ROSAT and Chandra), EUV (GALEX), optical (2MASS), and infrared (WISE) bands to complete the SED. The continuum and emission-line measurements from the SDSS spectra and accompanying photometry provides estimates on the black hole masses, bolometric luminsosities, and SED. We consider empirically how these affect the outflow properties.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 09-ADP09-0016 issued through the Astrophysics Data Analysis Program.

335.1 – **Characterizing Quasar Outflows II: The Incidence of the Highest Velocity Outflows**

Michele A. Stark[1], R. Ganguly[1], D. H. Christenson[1], J. M. Richmond[1], J. A. Derseweh[1], J. M. Robbins[1], S. L. Townsend[1]

[1]*University of Michigan - Flint.*

9:00 AM - 6:30 PM

Galaxy evolution models have shown that quasars are a crucial ingredient in the evolution of massive galaxies. Outflows play a key role in the story of quasars and their host galaxies, by helping regulate the accretion process, the star-formation rate and mass of the host galaxy (i.e., feedback). The prescription for modeling outflows as a contributor to feedback requires knowledge of the outflow velocity, geometry, and column density. In particular, we need to understand how these depend on physical parameters and how much is determined stochastically (and with what distribution). For this purpose, we are examining a sample of 11000 z=1.7-2.0 quasars from the Sloan Digital Sky Survey. This redshift range permits the following from the SDSS spectra: (1) separation of objects that do and do not exhibit outflows; (2) classification/measurement of outflow properties (ionization, velocity, velocity width); and (3) measurements of UV emission line and continuum parameters. In an accompanying poster, we subjectively divide these quasars into four categories (broad absorption-line quasars, associated absorption-line quasars, reddened quasars, and unabsorbed/unreddened quasars). This subjective scheme is limited with regard to classifying narrow absorption-line systems (NALs). With single epoch, low dispersion SDSS spectra, we cannot distinguish between cosmologically intervening NALs, and intrinsic NALs that appear at large velocity offsets. In this poster, we tackle this uncertainty statistically by considering the incidence of both CIV and MgII NALs as a function of velocity, and how this distribution changes with quasar properties. We expect that absorption by intervening structures should not vary with quasar property. Other accompanying posters add photometry from rest-frame X-ray through the infrared (WISE) to complete the SED, which we utilize in these efforts.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 09-ADP09-0016 issued through the Astrophysics Data Analysis Program.

335.11 – **Characterizing Quasar Outflows III: SEDs, and Bolometric Luminosity Estimates**

Joseph Richmond[1], J. M. Robbins[1], R. Ganguly[1], M. A. Stark[1], D. H. Christenson[1], J. A. Derseweh[1], S. L. Townsend[1]

[1]*University of Michigan - Flint.*

9:00 AM - 6:30 PM

Galaxy evolution models have shown that quasars are a crucial ingredient in the evolution of massive galaxies. Outflows play a key role in the story of quasars and their host galaxies, by helping regulate the accretion process, the star-formation

rate and mass of the host galaxy (i.e., feedback). The prescription for modeling outflows as a contributor to feedback requires knowledge of the outflow velocity, geometry, and column density. In particular, we need to understand how these depend on physical parameters and how much is determined stochastically (and with what distribution). For this purpose, we are examining a sample of 11000 z=1.7-2.0 quasars from the Sloan Digital Sky Survey. This redshift range permits the following from the SDSS spectra: (1) separation of objects that do and do not exhibit outflows; (2) classification/measurement of outflow properties (ionization, velocity, velocity width); and (3) measurements of UV emission line and continuum parameters. In this poster, we add photometry from both the Two Micron All-Sky Survey (2MASS) and from the Wide-Field Infrared Survey Explorer (WISE). 2MASS photometry covers the rest-frame optical regime of these qusars, while the WISE W1, W2, and W3 bands cover the rest-frame wavelength ranges 0.9-1.27 micron, 1.35-1.75 micron, and 2.52-5.51 micron, respectively. The preliminary release of WISE data cover 3800 of our quasars. In an accompnying poster, we have subjectively divided these quasars into four categories: broad absorption-line quasars (2700 objects), associated absorption-line quasars (1700 objects), reddened quasars (160 objects), and unabsorbed/unreddened quasars (6300 objects). Here, we present average SEDs for these subsamples, estimates of bolometric luminosity, and explore changes in SED based on both outflow properties and quasar physical properties.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 09-ADP09-0016 issued through the Astrophysics Data Analysis Program.

335.12 – **Characterizing Quasar Outflows IV: Regulating Outflows Through X-ray and EUV Absorption**

Jeffrey Derseweh[1], R. Ganguly[2], J. M. Richmond[2], M. A. Stark[2], D. H. Christenson[2], J. M. Robbins[2], S. L. Townsend[2]

[1]UMFlint, [2]University of Michigan - Flint.

9:00 AM - 6:30 PM

Galaxy evolution models have shown that quasars are a crucial ingredient in the evolution of massive galaxies. Outflows play a key role in the story of quasars and their host galaxies, by helping regulate the accretion process, the star-formation rate and mass of the host galaxy (i.e., feedback). The prescription for modeling outflows as a contributor to feedback requires knowledge of the outflow velocity, geometry, and column density. In particular, we need to understand how these depend on physical parameters and how much is determined stochastically (and with what distribution). For this purpose, we are examining a sample of 11000 z=1.7-2.0 quasars from the Sloan Digital Sky Survey. This redshift range permits the following from the SDSS spectra: (1) separation of objects that do and do not exhibit outflows; (2) classification/measurement of outflow properties (ionization, velocity, velocity width); and (3) measurements of UV emission line and continuum parameters. In this poster, we add photometry from the GALEX All-sky imaging survey, as well as the Chandra and ROSAT archives. These provide coverage of the rest-frame extreme ultraviolet, and soft X-ray bands. In an accompanying poster, we have subjectively divided these quasars into four categories: broad absorption-line quasars (2700 objects), associated absorption-line quasars (1700 objects), reddened quasars (160 objects), and unabsorbed/unreddened quasars (6300 objects). We are interested in testing the radiative-driving hypothesis that requires a suppression of X-ray flux in order to transfer momentum efficiently to the UV-absorbing gas. Hence, we explore how absorption in both the extreme ultraviolet and the soft X-ray bands correlate with properties of the UV outflows, quasar property, and changes in SED shape.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 09-ADP09-0016 issued through the Astrophysics Data Analysis Program and by Chandra grant GO9-0120X.

335.13 – **Quasar Spectral Energy Distributions As A Function Of Physical Property**

Shonda Townsend[1], R. Ganguly[1], M. A. Stark[1], J. A. Derseweh[1], J. M. Richmond[1]

[1]University of Michigan - Flint.

9:00 AM - 6:30 PM

Galaxy evolution models have shown that quasars are a crucial ingredient in the evolution of massive galaxies. Outflows play a key role in the story of quasars and their host galaxies, by helping regulate the accretion process, the star-formation rate and mass of the host galaxy (i.e., feedback). The prescription for modeling outflows as a contributor to feedback requires knowledge of the outflow velocity, geometry, and column density. In particular, we need to understand how these depend on physical parameters and how much is determined stochastically (and with what distribution). In turn, models of outflows have shown particular sensitivity to the shape of the spectral energy distribution (SED), depending on the UV luminosity to transfer momentum to the gas, the X-ray luminosity to regulate how efficiently that transfer can be, etc. To investigate how SED changes with physical properties, we follow up on Richards et al. (2006), who constructed SEDs with varying luminosity. Here, we construct SEDs as a function of redshift, and physical property (black hole mass, bolometric luminosity, Eddington ratio) for volume limited samples drawn from the Sloan Digital Sky Survey, with photometry supplemented from 2MASS, WISE, GALEX, ROSAT, and Chandra. To estimate black hole masses, we adopt the scaling relations from Greene & Ho (2005) based on the H-alpha emission line FWHM. This requires redshifts less than 0.4. To construct volume-limited subsamples, we begin by adopting g=19.8 as a nominal limiting magnitude over which we are guaranteed to detect z<0.4 quasars. At redshift 0.4, we are complete down to Mg=-21.8, which yields 3300 objects from Data Release 7. At z=0.1, we are complete down to Mg=-18.5.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 09-ADP09-0016 issued through the Astrophysics Data Analysis Program.

335.14 – **VLA/EVLA Monitoring of Planck Sources**

Noah Kurinsky[1], A. Sajina[1], B. Partridge[2], S. Myers[3]

[1]Tufts University, [2]Haverford College, [3]National Radio Astronomy Observatory.

9:00 AM - 6:30 PM

We report VLA/EVLA observations of 98 predominantly S 37 > 1 Jy northern hemisphere sources observed at 4.8, 8.5, 33.5, and 43.3 GHz within about two weeks of the observations of the same sources made by ESA's Planck mission. These observations allow us to: 1) validate Planck's 30 and 44 GHz flux density scale, 2) extend the radio SEDs of Planck sources to lower frequencies allowing for the full 5-857GHz regime to be studied, and 3) characterize the variability of these sources. At 30 GHz the ERCSC, and the EVLA flux densities agree to within 2%, and at 44 GHz they agree to within 3%. Multiple epoch VLA/EVLA observations for most of the sources allow us to do a variability analysis. On timescales of less than a month the median variability of our sources is only 3%, though a tail of highly variable sources is also present. On timescales of a few months, the median variability is 6% while on

timescales of a year or longer the median variability increases to 14%.

335.15 – **The Energetics of Quasar Broad Absorption Line Outflows**

Daniel M. Capellupo[1], F. Hamann[1], K. Leighly[2], D. Terndrup[3], M. Dietrich[3], S. Gallagher[4], J. C. Shields[5]

[1]University of Florida, [2]Univ. of Oklahoma, [3]Ohio State Univ, [4]Univ of Western Ontario, Canada, [5]Ohio University.

9:00 AM - 6:30 PM

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. In order to determine the viability of these outflows as a feedback mechanism, we need estimates of their mass outflow rates and kinetic energy yields. These quantities depend on the column densities of the flows, which are difficult to obtain directly from spectra of the BALs. To address this problem, we turn to a low-abundance species, PV λ1118, 1128. Phosphorus is much less abundant than, for example, carbon (about 1000 times less abundant in the Sun), so a detection of a PV BAL indicates that other lines, such as the well-studied CIV λ1550 BAL, are saturated. We detect variability in a PV BAL in Q1413+1143, corresponding to variable SiIV λ1400 and CIV BALs. The variability in the PV BAL confirms that the absorption is intrinsic to the quasar and provides a constraint on the location of the gas. Using the apparent optical depth of the PV BAL and photoionization models, we can constrain the true column density of the outflow. With constraints on the location and column density, we estimate the kinetic energy yields and compare to simulations to estimate the viability of the outflow as a feedback mechanism. We also search through archival data to estimate the overall incidence of PV absorption in BAL quasar spectra.

335.16 – **EVLA Observations of FR II Radio Sources with Candidate Relativistic Hotspots**

Alexander M. Chartrand[1], B. P. Miller[2], W. N. Brandt[3], M. P. Gawronski[4], S. E. Cederbloom[5]

[1]Bryn Mawr College, [2]University of Michigan, [3]Pennsylvania State University, [4]Nicolaus Copernicus University, Poland, [5]University of Mount Union.

9:00 AM - 6:30 PM

We have identified six FR II radio sources that are candidates to possess hotspots with modestly relativistic (0.2 < v/c < 0.7) bulk velocities, in contrast to the vast majority of FR II radio sources that possess non-relativistic hotspot bulk velocities (e.g., v/c = 0.03 +/- 0.02 from Scheuer 1995). These candidates were selected based on their arm-length and flux-ratio asymmetries from a parent sample of ~900 SDSS/FIRST double-lobed radio-loud quasars. For the four candidates lacking higher-resolution radio mapping, we obtained EVLA observations at 5 GHz to confirm the hotspot parameters, to measure their radio spectral indices, and to check for the presence of any jets. The observations were carried out on 12 June 2011 using 27 antennas in the A configuration. For one candidate, the morphology is found to be likely contaminated by an unrelated intruding source. For two candidates, the fainter lobes are not detected at 5 GHz. Simulations suggest that 4-6/900 objects may randomly display asymmetries (e.g., due to environmental interactions) as found for the candidates. It is ruled out that the candidates are young sources observed prior to deceleration of their hotspots because their intrinsic lobe distances are not abnormal for FR II sources. While it remains possible that a few of the candidates possess long-lived relativistic hotspots (e.g., one object shows additional supportive evidence in the form of a one-sided jet aligned with the brighter hotspot), we conclude that relativistic hotspots are extremely rare (<0.5%) or absent within double-lobed radio-loud quasars.

335.17 – **The Unique Diagnostic Infrared Colors of Blazars: The WISE Blazar Strip**

Howard Alan Smith[1], F. Massaro[2], R. D'Abrusco[1], M. Ajello[2], D. Gasparrini[3], J. E. Grindlay[1]

[1]Harvard-Smithsonian, CfA, [2]SLAC National Laboratory and Kavli Institute for Particle Astrophysics and Cosmology, [3]ASI Science Data Center, ESRIN, Italy.

9:00 AM - 6:30 PM

We have discovered that the mid-infrared colors of blazars are a powerful tool for their identification. We have used this diagnostic to identify probable new blazars, including some gamma-ray sources, and to begin to address the physical mechanism(s) responsible. From a sample of 1365 previously known blazars (from

the ROMA BZCAT) observed in the first release of the WISE Preliminary Source catalog we prepared a color-color analysis; additional objects will be incorporated after the full WISE data release. We find that blazars lie on a narrow strip in [3.4]-[4.6] vs [4.6]-[12] colors. The strip is distinctly redder on average at the short bands than either average stars, starbursts, LIRGS, ULIRGS or LINERS, and is of intermediate redness in the longer wavelength bands. Similar narrow strips can be defined with other combinations of WISE colors, and in color-magnitude plots. The defining width of the "WISE blazar strip" is quite restrictive - only about 0.6 mag. We will present results, analyses, and a discussion of the implications of this property of blazars. This work was supported in part by NASA grants NNX10AD50G and NNX10AD68G

335.18 – **Magnetic Domination of 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

Relativistic jets such as those emitted by active galactic nuclei are observed to be collimated over great distances, but the cause of the initial collimation is uncertain. To probe this question, we examine the possibility of collimation of relativistic magnetohydrodynamic jets by the pressure of the ambient medium. We follow up a hydrodynamic study in previous work, assuming now that the jet is threaded by a toroidal magnetic field, and we examine the limit in which the jet interior has lost causal contact with its surroundings. We model the jet with an ultrarelativistic equation of state, injected into an ambient medium with a pressure that decreases as a power of spherical radius, p ~ r^{-n}. Within the range 2<n<4, the jet interior will be out of causal contact but the outer layers of the jet gradually collimate toward the jet axis, leading to the formation of a shocked boundary layer. By constructing partially self-similar solutions to the fluid equations within this boundary layer, we examine the structure of the jet and the impact of the external pressure profile on the behavior of the fluid in the layer. We show that the jet will eventually grow to become magnetically dominated far from the source. When magnetic pressure dominates, physical self-similar solutions are admitted in which the total pressure within the layer decreases linearly from the contact discontinuity inward. These solutions suggest a ‘hollow cone’ behavior of the jet, with the boundary layer thickness prescribed by the value of n.

335.19 – **Monte Carlo Simulations of the Clumpy Torus: Implications for X-ray and Optical Obscuration**

Karen T. Lewis[1], K. Ramic[1]

[1]*College of Wooster.*

9:00 AM - 6:30 PM

In the standard model of AGN, many observational differences between AGN are attributed to obscuration by a dusty, equatorial torus.

Infrared observations strongly suggest that the obscuring medium is clumpy. This has important implications for observations at other wavelengths; whether an AGN appears obscured at any given moment becomes a matter of statistical probability, although the probability of obscuration increases greatly for large inclination angles. It has been suggested that the clumsiness of the torus might be important for understanding sources in which the level of obscuration in the X-ray and optical are discrepant (e.g. AGN with only narrow emission lines but minimal X-ray absorption.) Because the broad emission line region is extended relative to the size of the clumps in the torus and the X-ray emission region is compact, there could be differences in the level X-ray and optical obscuration at different times, but even perhaps for simultaneous observations. In this poster we present preliminary results of Monte Carlo simulations of various torus geometries. We find that there is significant variation in the level of obscuration for observers with different azimuthal angles (a proxy for non-simultaneous observations). However for a given observer line of sight there is no discernible difference in the level of obscuration in the X-ray and optical for torus geometries that are similar to those used to model the infrared observations.

335.2 – **A Decade of Circular Polarization Measurements at Centimeter Wavelengths**

Hugh D. Aller[1], M. F. Aller[1]

[1]*Univ. of Michigan.*

9:00 AM - 6:30 PM

The University of Michigan 26-Meter paraboloid has been used to monitor the integrated emissions of over a dozen active extragalactic objects at 4.8, 8.0, and 14.5 GHz in all four Stokes parameters for the past decade. Several of these objects, which are predominantly QSOs, have exhibited significant circularly polarized emission (Stokes V) with amplitudes as large as one percent at some epochs. We show examples and discuss their behavior. The variability observed includes temporal changes in polarity at a single frequency, frequency-dependent differences in polarity at a single epoch, and long-term ordered changes in amplitude. This research was supported in part by funds from NSF grant AST-0607523.

335.21 – **Evolution of Quasar Spectral Energy Distributions**

Amanda Schilling[1], J. Kennefick[1], A. Mahmood[1]

[1]*University of Arkansas, Fayetteville.*

9:00 AM - 6:30 PM

A common practice when formulating quasar luminosity functions (QLF) has been to adopt an average spectral index, $alpha$, for the sample even though it is well known that quasars exhibit a broad range of spectral energy distributions (SED.) We have investigated the possible evolution of $alpha$ as a function of redshift, as any evolution in this parameter would introduce or mask evolution in the QLF. We imaged 103 Sloan Digital Sky Survey (SDSS) quasars in the optical and near-infrared bands, near in time to mitigate the effects of variability, in three redshift bins centered at $zapprox 1.9$, 2.7, and 4.0, corresponding to look-back times of 10-12 billion years. We present restframe UV-optical SED’s and spectral indices and discuss possible evolution in our sample. We also use single epoch spectra of the quasars to estimate the mass of the central black hole and discuss possible correlations of quasar properties such as mass, luminosity, and spectral shape.

335.22 – **BVRI Observations Of Fermi-detected Blazars**

Daryl J. Macomb[1], J. P. Norris[1]

[1]*Boise State Univ..*

9:00 AM - 6:30 PM

We describe initial results from the continuing blazar monitoring program at the Challis Astronomical Observatory (CAO). The remotely operable, 0.4 m CAO is located in central Idaho at 2165 m elevation, in a dry mountain desert micro-climate. CAO accesses targets with Declination > -20 degrees. The CAO blazar sample includes 50 sources - comprising 30 FSRQs, 15 BL Lacs, one radio galaxy and four unclassified sources - covering a redshift range 0.02 < z < 2. Observations are carried out in BVRI filters. We present lightcurves for several sources, focusing on blazars with concurrent Fermi/LAT detected flares, over the period 2010 Oct to 2012 May

335.23 – **Optical And Near-infrared Variability Among Distant Galactic Nuclei Of The CANDELS COSMOS Field**

Norman A. Grogin[1], A. Rajan[1], J. L. Donley[1], J. S. Kartaltepe[2], A. M. Koekemoer[1], R. A. Lucas[1], D. J. Rosario[3], M. Salvato[3]

[1]*Space Telescope Science Institute,* [2]*National Optical Astronomy Observatory,* [3]*Max Planck Institute for Extraterrestrial Physics, Germany.*

9:00 AM - 6:30 PM

The CANDELS HST Multi-cycle Treasury Program completed its observations of the COSMOS field in February 2012. The coverage comprises WFC3/IR exposures in J-band and H-band across a contiguous 185 square arcminutes, and coordinated parallel ACS/WFC exposures in V-band and I-band across a contiguous 230 square arcminutes that largely overlaps the WFC3/IR coverage.

These observations were split between two epochs with 52-day spacing for the primary purpose of high-redshift supernovae (SNe) detection and follow-up. However, this combination of sensitivity, high resolution, and time spacing is also well-suited to detect optical and near-infrared variability ("ONIV") among moderate- to high-redshift galaxy nuclei (H<25AB mag; I<26AB mag). These data are sensitive to rest-frame variability time-scales of up to several weeks, and in combination with the original COSMOS ACS imaging from 2003, to time-scales of up to several years in the I-band.

The overwhelming majority of these variable galaxy nuclei will be AGN; the small fraction arising from SNe have already been meticulously culled by the CANDELS high-redshift SNe search effort. These ONIV galaxy nuclei potentially represent a significant addition to the census of distant lower-luminosity AGN subject to multi-wavelength scrutiny with CANDELS.

We present the preliminary results of our COSMOS variability analysis, including a comparison of the HST ONIVs with the known AGN candidates in the field from deep Spitzer and Chandra imaging, and from extensive ground-based optical spectroscopy as well as HST IR-grism spectroscopy. We also assess the redshift distribution of the ONIVs from both spectroscopy and from robust SED-fitting incorporating ancillary deep ground-based imaging along with the CANDELS VIJH photometry.

We compare these results with our prior variability analysis of the similarly-observed CANDELS UDS field from 2011.

335.24 – **Galaxy Zoo: Testing the Relationship between AGN Identification and Host Galaxy Inclination**

Stephanie M. LaMassa[1], K. Schawinski[1], J. Parejko[1], C. Urry[1], K. Masters[2], W. Keel[3], C. Lintott[4]

[1]*Yale University,* [2]*University of Portsmouth, United Kingdom,* [3]*University of Alabama,* [4]*Oxford University, United Kingdom.*

9:00 AM - 6:30 PM

According to the AGN unification model, Type 1 and Type 2 AGN are the same physical object: an accreting supermassive black hole in a galactic center surrounded by anisotropic circumnuclear obscuration. In Type 1 systems, the accretion disk is viewed directly whereas it is blocked from view in the Type 2 AGN. Previous studies have tested whether the inclination of the accretion disk is aligned with the host galaxy, but these samples have been limited to relatively small numbers. Utilizing the rich data set provided by Galaxy Zoo and the Sloan Digital Sky Survey (SDSS), we increase the sample size of previous works by over an order of magnitude to test if Type 1 or Type 2 identification relates to host galaxy inclination. Using axial ratio b/a measurements calculated homogeneously from the SDSS pipeline and Galaxy Zoo classifications as to whether a galaxy is viewed "edge-on," we show that Type 1 AGN tend to avoid edge-on host systems compared with Type 2 AGN.

336 – Evolution of Galaxies

336.01 – **Tensor Smoothed Particle Hydrodynamics**

Brandt Gaches[1]

[1]*University of Arizona.*

9:00 AM - 6:30 PM

This paper presents a novel SPH method, called Tensor SPH (TenSPH for short) that introduces a metric into computing the motion of a particle in a Lagrangian fluid. First, the definition of the tensor metric and the new distance scale is introduced. The new SPH formalism is then derived, which is shown to reduce to the conventional formalism for a uniform fluid. The equations of motion for a fluid that is acting in Reimannian geometry are then derived, yielding new equations of motions that have corrections terms new to SPH. This paper also introduces a new type of viscosity function, derived purely from first principles, that emerges from the formalism of TenSPH; in principle, this viscosity function could remove the dependence of SPH of "artificial" viscosity. The new method for nearest neighbor searching is also described. The results of TenSPH in standard tests are shown to better account for discontinuities in density, without having any negative side effects. TenSPH is a form of SPH that is able to naturally simulate any type of initial conditions, using equations that are derived purely from first principles.

336.02 – **Galactic Disks in Triaxial Dark-Matter Halos and the Bulge-Halo Connection**

Clayton H. Heller[1], H. Seddiqi[1]

[1]*Georgia Southern Univ..*

9:00 AM - 6:30 PM

In this study we examine the role triaxial dark-matter halos play in bulge formation by inducing a gaseous inflow in the inner parts of galactic disks. In a series of hydrodynamic simulations we measure the inflow due to the formation of shocks in a galactic disk by a triaxial potential. The inflow of gas contributes to the formation of a bulge which weakens the non-axisymmetry of the halo potential in the disk plane, providing a negative feedback on the inflow. The resulting correlation between halo and bulge mass are examined and compared to observations.

336.03 – **The Fine Structure in the Low Column Density HI Bridge between M31 and M33**

Spencer Wolfe[1], D. Pisano[1], F. J. Lockman[2], S. McGaugh[3], E. Shaya[3]

[1]*West Virginia University,* [2]*NRAO,* [3]*University of Maryland.*

9:00 AM - 6:30 PM

We present results from a project to map the low column density HI bridge between M31 and M33 using the Robert C. Byrd Green Bank Telescope. This emission was first detected by Braun & Thilker (2004) at a three-sigma column density sensitivity of 10^17 cm^(-2), but with poor angular resolution. We have mapped a 12 square degree region between M31 and M33 with the GBT to understand how this gas is distributed and to determine whether it is the result of a tidal interaction or perhaps due to accretion from a cold flow. Our current results show that some of this gas is arranged in higher column density clumps on spatial scales smaller than those of the Braun & Thilker resolution. Our data will also be used as a constraint to a least action based model in order to better understand the orbital history of the M31-M33 system.

336.04 – **The Zurich Environmental Study (ZENS): Galaxy Evolution in Groups in the Nearby Universe**

Craig Rudick[1], M. Carollo[1], A. Cibinel[1], A. Pipino[1], T. Lu[1], E. Cameron[1], S. Lilly[1], Y. Peng[1], F. Miniati[1], S. Bonoli[2], J. Silverman[3], J. van Gorkum[4]

[1]*ETH Zurich, Switzerland,* [2]*MPA, Germany,* [3]*IPMU, Japan,* [4]*Columbia.*

9:00 AM - 6:30 PM

ZENS is a survey of nearby (z~0.05) galaxy groups in the mass range ~10^{12}-10^{14} M_{SUN}. From both spectroscopy and deep optical imaging, we have analyzed the structural, stellar population, and star-formation properties of the group galaxies. By comparing the galaxy populations, at fixed galactic stellar mass, across a wide range of environmental indicators - including group halo mass, group-centric radius, large scale structure density, and satellite vs. central galaxies - we are able to determine the dependence of galactic properties on each of these environmental measures. Our results indicate that the most significant environmental effects are seen for satellite galaxies as a function of the group-centric distance, where galaxies nearer the group centers are more likely to be quenched, be more bulge-dominated, and have redder colors (particularly in the disk component) than galaxies in the group outskirts. Group halo mass, LSS-density, and the central/satellite dichotomy tend to have smaller, although not always negligible, effects. Additionally, the group environment has a more pronounced affect on galaxies at lower stellar masses. We compare these results to those of several state-of-the art semi-analytic models of galaxy evolution. We find that the standard recipes tend to predict both an over-abundance of, and overly red colors for quenched galaxies. We instead find that a model in which the star-formation rate of galaxies is tied to the observed specific star formation evolution with redshift more accurately reproduced the numbers and colors of these quenched galaxies.

336.05 – **Investigating Massive Outflow from Radio Loud AGN**

Hsin-Yi Shih[1]

[1]*University of Hawaii.*

9:00 AM - 6:30 PM

Feedback from supermassive black holes plays the important role of quenching star formation and black hole growth in galaxy evolution models. One form of massive outflow caused by black hole feedback can be observed as extended emission-line regions (EELRs) that are known to exist around a significant fraction of low redshift AGNs with strong radio jets. We are investigating the driving mechanism and physical characteristics of the EELRs in a three part project: (1) To catch the outflows in their infancy, we observed compact-steep-spectrum (CSS) sources with young and powerful radio structures using the integral field unit (IFU) on Gemini North. (2) To understand the 3-D gas distribution in the EELRs, we surveyed a significant matched sample of FR II radio galaxies and quasars (which are suppose to be the same type of object viewed from different projection angles). (3) To further investigate the physical properties such as densities, metallicities, velocity field, photoionization parameter, and possible evidence for shocks in EELRs, we have obtained HST STIS spectra of the high velocity outflow component found around the quasar 3C 48. Our poster will provide a brief description of the results from each of the above studies.

336.06 – **The Emission Line Objects At 0<z<1.7 As Seen By PEARS**

Norbert Pirzkal[1], S. Malhotra[2], J. J. E. Rhoads[2], C. Ly[1], B. Rothberg[3], T. Dahlen[1]

[1]*STScI,* [2]*ASU,* [3]*George Mason.*

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 Ha, OIII, OII, Hg and Lya lines, over a redshift range of 0<z<7.2. Most of the lines we identified are Ha (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 Ha, OII, and OIII computed across these relatively broad redshift ranges using both the Vmax and STY methods and investigate the redshift dependence of these luminosity functions, and the physical distribution of the emission line regions we detect.

336.07 – **The Mass-Metallicity Relation of Emission Line Selected Galaxies from HST Slitless Spectroscopy**

James E. Rhoads[1], L. Xia[1], S. Malhotra[1], N. Pirzkal[2], A. Straughn[3], S. Finkelstein[4], S. Cohen[1], H. Kuntschner[5], M. Kuemmel[5], J. Walsh[5], R. A. Windhorst[1], R. O'Connell[6]

[1]*Arizona State Univ.,* [2]*Space Telescope Science Institute,* [3]*NASA GSFC,* [4]*University of Texas,* [5]*European Southern Observatory, Germany,* [6]*University of Virginia.*

9:00 AM - 6:30 PM

Galaxies selected on the basis of their emission line strength show low metallicities, regardless of their redshifts. We conclude this from a sample of faint galaxies at redshifts between 0.2 < z < 2.4, selected by their prominent emission lines in low-resolution grism spectra. These include samples selected in the optical from the PEARS HST treasury survey, using slitless spectroscopy from the HST Advanced Camera for Surveys; and in the near-infrared, selected from WFC3-IR grism data from the WFC3 Early Release Science program. Where needed, we combine these HST data with followup spectroscopy from Magellan to obtain additional emission line fluxes. We study the metallicities using the R23 indicator. We determine stellar masses from spectral energy distribution fitting of the multiwavelength data in these well-studied HST deep fields. The full sample spans a mass range of 7.5 < log(M/Msun) < 10.5 and a range of gas-phase oxygen abundances 7.5 < 12 + log(O/H) < 8.9. The metallicities of these objects are significantly lower than usual for galaxies of comparable redshift and stellar mass, with an offset of about -0.7 dex in the mass-metallicity relation. On the other hand, the mass-metallicity location of these emission line selected objects resemble those of "green pea" galaxies in the nearby universe, and of Lyman alpha selected objects at both redshift 0.3 and 2.3.

336.08 – **Searching for the Progenitors of High-redshift Compact Elliptical Galaxies**

Christina Williams[1], M. Giavalisco[1], P. Cassata[2], Y. Guo[1]

[1]*University of Massachusetts, Amherst,* [2]*Laboratoire d'Astrophysique de Marseille, France.*

9:00 AM - 6:30 PM

High-redshift galaxy surveys have revealed a population of very massive and already evolved early-type galaxies at z > 1, which appear to be ultra-compact in size relative to local galaxies of similar stellar mass. The compactness and stellar masses of these galaxies, which are already in place at high-redshift, pose challenges for theories in which mergers drive the evolution of galaxies. We investigate the properties of Lyman Break Galaxies at z > 3 in CANDELS, among whom must be the progenitor population of these ultra-compact early-type galaxies, to assess the extent to which they were also ultra-compact while building up their stellar mass. Since merging and accretion generally increase the size of galaxies, the progenitors of the ultra-compact ellipticals must be compact star-forming galaxies themselves. Using rest-frame optical imaging from HST and SED fitting, we study the evolution in the mass-radius relation using their

morphologies and stellar masses. We also discuss the implications that these ultra-compact star-forming galaxies have on theories of galaxy evolution and the quenching of star-formation at high-redshift.

337 – AAS Sustainability Committee

Special Session – Summit Hall 4, Egan Center – 6/12/2012 10:00:00 AM to 6/12/2012 11:30:00 AM

The AAS Sustainability Committee aims to reduce the ecological footprint of the AAS and its operations. This special session will focus on the energy use and greenhouse gas emissions associated with AAS conferences and how we can reduce them.

400 – SPD Parker Lecture: How to Observe (Rather Than Model) The Interiors of Stars

Invited Session – Ballroom B, Dena'ina Center – 6/13/2012 8:30:00 AM to 6/13/2012 9:20:00 AM

400.01 – **How to Observe (Rather Than Model) The Interiors of Stars**

Yvonne Elsworth[1]

[1]*University of Birmingham, United Kingdom.*

8:30 AM - 9:20 AM

Seismology - the study of the propagation of sound waves - allows us to make real observations of the interior of stars and provides a vital counterpoint to the inferences of theory. Helioseismology pioneered this activity and an autonomous small network (BiSON) run from the University of Birmingham (UK) has been making seismic observations of the Sun for more than three solar cycles. Its continuing observations have included the just past rather strange minimum. I will use some of the recent data to illustrate the curious behaviour of our home star.

For other stars there have been several recent breakthrough missions. Foremost in these is the NASA Kepler mission which has opened up to view a very large number of stars. The prime aim of the Kepler mission is the hunt for earth-like planets and the role of the seismic analysis is to inform about the host stars. However, the observations of the stars are very important in their own right. My particular interest is in the solar-like main sequence stars and red giants. I will discuss some of the recent exciting results.

Given that we can now observe the interior of stars like the Sun and also stars like the Sun will - in time - become, there is every hope that we will see major in our knowledge of stellar populations, structure and evolution.

401 – Bridging Laboratory and Astrophysics: Plasmas

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying plasma processes which drive our cosmos.

401.01 – **What is a Jet? Experimental, Observational and Theoretical Studies of Astrophysical Outflows**

Adam Frank[1]

[1]*Univ. of Rochester.*

10:00 AM - 10:30 AM

After more than 30 years of study, many foundational questions about the structure and dynamics of collimated astrophysical outflows remains uncertain. In this talk I review coordinated studies of astrophysical outflows that rely on traditional observational and simulation based approaches as well as new High Energy Density Laboratory Astrophysics experiments. Our work demonstrates that rather than continuous beams of plasma, astrophysical outflows may be heterogenous - i.e. jets are essentially hypersonic buckshock. In addition launching by magnetic tower processes, rather than the magneto-centrifugal process, may be more common than previously thought.

401.02 – **Magnetic Reconnection in Solar, Space, and Laboratory Plasmas**

Nicholas Arnold Murphy[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*

10:30 AM - 11:00 AM

Magnetic reconnection is a ubiquitous process in space, astrophysical, and laboratory plasmas. Observations of reconnection in the solar corona, such as those by the X-Ray Telescope on Hinode and the Atmospheric Imaging Assembly on the Solar Dynamics Observatory, allow us to study the large-scale consequences and dynamics of reconnection but provide only indirect information on the small-scale physics of energy release. In situ observations of reconnection in space plasmas provide detailed small-scale information, but at a very small number of points. Laboratory experiments allow both local and global dynamics to be studied with much more experimental control, but at relatively modest dimensionless parameters and separation of scales. In this talk, I will review recent progress using these different types of investigations, and discuss the need for taking these three complementary approaches to understand the fundamental physics of magnetic reconnection.

401.03 – **Study of Angular Momentum Transport in Laboratory Flows Relevant to Accretion Disks**

Hantao Ji[1]

[1]*Princeton Plasma Physics Laboratory.*

11:00 AM - 11:30 AM

Rapid angular momentum transport in accretion disk plasmas has been a longstanding astrophysical puzzle. Since Keplerian flows are linearly stable in hydrodynamics, there exist two major candidates to generate the required turbulent transport: the nonlinear hydrodynamic instability or the linear magnetorotational instability (MRI). Rigorous efforts to demonstrate and study these instabilities in the laboratory started only in recent years but significant insights relevant to accretion disks have been already obtained, with many surprises. The recent achievements, current status and future prospects of these efforts, including past relevant experiments, will be discussed in this talk in three categories: hydrodynamic, magnetohydrodynamic, and gas/plasma experiments.

402 – Wide-Field IR Space Telescope Science: Exoplanet Science

Meeting-in-a-Meeting – Summit Hall 3, Egan Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

The Astro2010 Decadal Survey gave its highest recommendation in the large-scale space mission category to WFIRST, a Wide-Field Infrared Survey Telescope with both imaging and spectroscopy capabilities. The science made possible by such a facility reaches across many disciplines from dark energy to exoplanets to deep surveys. The exoplanet studies will be done using the microlensing technique. Observing campaigns will be made of regions in the galactic bulge with dense star fields. Exoplanets will be found by microlensing amplifications of planetary systems and isolated free-floating planets. The exoplanet science aspects of WFIRST will be discussed in this session.

402.01 – **Space Microlensing Exoplanet Survey with WFIRST**

Takahiro Sumi[1]

[1]*Osaka University, Japan.*

10:00 AM - 10:30 AM

We review the capabilities and scientific goals of the WFIRST microlensing exoplanet survey. The wide field infrared capability of WFIRST is optimal to detect short-lived planetary signals by obtaining continuous high cadence light curves of millions of stars in the galactic bulge with excellent photometric accuracy. This is critical for collecting large unbiased sample of planets with wide range of mass and period from habitable Earth-mass planets to free floating planets, including analogs to all of the planets in our Solar System except Mercury. WFIRST is expected to detect ~3000 planets including ≥ 125 planets of 1 Earth mass in 2 year orbits and ≥ 25 habitable zone planets (0.5 to 10 Earth mass), and ~2000 free floating planets including ≥ 30 free floating planets of 1 Earth mass, in a 500 day survey assuming one such planet per star. WFIRST completes the statistical census of planetary systems in the Galaxy.

402.02 – **WFIRST Planetary Microlensing Capabilities and Hardware Accommodations**

Edward S. Cheng[1]

[1]*Conceptual Analytics.*

10:30 AM - 11:00 AM

The WFIRST mission will provide the first large-scale implementation of the planetary microlensing technique for exoplanet discovery. From its vantage point in space, it enjoys the benefits of near-continuous coverage of light curves over a very large field in the Galactic Bulge with exceptional point-spread-function and photometric stability. These data sets, planned to extend for up to 2-3 months per campaign, will provide insights into planetary populations that will complement those discovered by Kepler and ground-based methods. Preliminary requirements on the WFIRST mission for realizing this capability are in place, and are relatively straightforward compared to the overall mission capability. Some aspects of the mission, such as the wide-area near-IR focal plane, are key to the microlensing observations and their development plans are reviewed.

402.03 – **Detection and Mass Determination for the Host Stars of Exoplanets Found by WFIRST**

David P. Bennett[1]

[1]*Univ. of Notre Dame.*

11:00 AM - 11:30 AM

Unlike exoplanets found by ground based microlensing surveys, exoplanets found by the WFIRST microlensing survey will come with high angular resolution imaging data that will, in most cases, allow the host stars to be detected in the imaging data. The detection of the host stars in the image data will be combined with the microlensing light curve information to determine the host star and planet masses, as well as their separation. A demonstration of this method with Hubble Space Telescope follow-up observations of exoplanet microlensing events observed from the ground will be presented. Additional methods to measure the masses of the planets found by WFIRST will also be discussed.

403 – Galaxy Mergers from the Largest to the Smallest Scales: Dual and Binary AGN

Meeting-in-a-Meeting – Room 2, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

Gas-rich galaxy mergers likely represent the phase in evolution during which major, rapid SMBH growth occurs. If accretion activity is triggered on both SMBHs, we observe dual AGN (wide pairs) and binary AGN (advanced stage of merging). These systems allow us to study accretion activity in the course of merging. In particular, this stage of evolution sets the conditions which later determine both the electromagnetic signals of SMBH binaries upon coalescence, and the magnitude of gravitational-wave induced recoil. After a decade-long search for dual AGN, the last ~2 years have seen many new discoveries, and this session summarizes these observations in the radio, optical, and X-ray bands.

403.01 – **Dual and Binary AGN**

Stefanie Komossa[1]

[1]*Max-Planck-Institut fuer Radioastronomie, Germany.*

10:00 AM - 10:20 AM

Galaxy mergers are important stages in galaxy evolution throughout cosmic history. Gas-rich mergers likely represent the sites of major black hole growth. Observing all stages of merging, from early galaxy interaction to binary supermassive black hole (SMBH) coalescence is therefore of great interest, and an active search for pairs and binaries of accreting SMBHs is currently ongoing. I will present a review of the different observations of spatially resolved systems from large to small scales, of astrophysical implications, and future schemes to search for more of them.

403.02 – **Resolving AGN in Close Pairs with Chandra Imaging Spectroscopic Observations**

Junfeng Wang[1]

[1]*Harvard-Smithsonian CfA/SAO.*

10:20 AM - 10:40 AM

Hierarchical galaxy merger models predict that the presence of massive black hole binaries should be common in the cores of galaxies. The seminal discovery of two hard nuclei with strong neutral Fe Kα lines in NGC 6240 demonstrates the power of high resolution X-ray imaging spectroscopy to unveil obscured AGN pairs. We present new results from our deep Chandra ACIS-S survey of nuclear regions in nearby Seyfert galaxies, in particular the X-ray discovery of a close pair of AGN in NGC 3393, separated by 150 pc. We discuss the constraints placed on the merger event.

403.03 – **Exploring Dual and Binary AGN via Radio Emission**

Sarah Burke Spolaor[1], J. Lazio[1]

[1]*Jet Propulsion Laboratory.*

10:40 AM - 11:00 AM

Dual and binary supermassive black holes (SMBHs) are thought to form as a direct result of a major galaxy merger. The discovery of late-stage SMBH pairs could critically inform upcoming gravitational wave science and cosmological formation models, and could provide fascinating studies of post-merger dynamics and merger-induced SMBH growth. However, it has been notoriously difficult to identify clear electromagnetic markers for dual and binary SMBHs in late-stage merger systems.

Accordingly, few definitive discoveries of paired SMBHs have yet been made, with only a handful of known systems at projected separations below 1kpc. We will review the unique contributions that radio imaging observations can make to this field: particularly in the search for new systems, the confirmation of candidate small-orbit binary systems, and the potential for multi-messenger gravitational wave science when combined with pulsar timing methods. We will also provide an update on recent radio searches for binary AGN.

We acknowledge that a portion of research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

403.04 – **Multiwavelength Observations of Dual AGN**

Julia M. Comerford[1]

[1]*The University of Texas.*

11:00 AM - 11:20 AM

Dual active galactic nuclei (AGN) with kpc-scale separations in merger-remnant galaxies are new observational tracers of the galaxy merger rate, black hole growth via gas accretion during mergers, and the black hole merger rate. I will discuss searches for dual AGN that employ multiwavelength observations, ranging from optical selection of suitable dual AGN candidates to confirmation of dual AGN through X-ray or radio detections of two AGN sources. I will outline the systematic observational approach that is underway to build a large catalog of dual AGN and present the dual AGN discovered from these observations to date.

This work is supported by NSF grant AST-1102525.

404 – Lyman Alpha Emitters as Probes of Galaxy Formation and Cosmology: Observed Properties

Meeting-in-a-Meeting – Summit Hall 2, Egan Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

Three 20+5 minute talks will be given summarizing observational knowledge of Lyman Alpha Emitting galaxies. Lyman Alpha Emitting galaxies represent galaxies in the early stages of bursts of star formation, and some may be primeval galaxies undergoing intitial starbursts. They have the lowest bolometric luminosity of any high-redshift population. Their correspondingly low dark matter halo masses imply that many are progenitors of typical present-day galaxies like the Milky Way. The session will conclude with a 15-minute moderated discussion of outstanding questions and how to resolve them.

404.01 – **The Observed Properties of Lyman Alpha Emitting Galaxies from Redshift z = 0 to 7**

Esther M. Hu[1]

[1]*Univ. of Hawaii, Institute for Astronomy.*

10:00 AM - 10:25 AM

Surveys of Lyman alpha emitters now have extensive coverage over a wide range of redshifts, with new results at both high and low redshift. I will discuss the current observational picture of LAEs and their properties with redshift, including the evolution of their luminosity function and maximum luminosity at each redshift from z=0 to 7. I will compare the evolution of the Lyman alpha luminosity function with the UV-determined continuum luminosity function.

404.02 – **The Physical Nature of Lyman-alpha galaxies**

Sangeeta Malhotra[1]

[1]*Arizona State Univ..*

10:25 AM - 10:50 AM

In the last few years we have progressed from merely finding Lyman-alpha galaxies to characterizing their physical properties using multiwavelength observations. We can now talk about their physical sizes, stellar and halo masses, ages, metallicities, and AGN fractions. Can we now answer why some (star-forming) galaxies at high redshift show bright Lyman-alpha emission whereas others don't? What is the escape fraction of Lyman-alpha photons? What helps these photons escape?

404.03 – **Using Lyman Alpha Galaxies as Tracers of the High-Redshift Universe**

Steven L. Finkelstein[1]

[1]*University of Texas.*

10:50 AM - 11:15 AM

Although we now routinely discover galaxies out to z > 7, we are limited in our ability to understand them as their faint nature restricts us to solely investigating their photometric properties. However, one can investigate their likely properties in more detail by examining galaxies at lower redshift that appear physically similar. Galaxies selected on the basis of bright Lyman alpha emission have been found to be on average bluer and lower-mass than their continuum selected counterparts, and thus appear similar to very high-redshift galaxies. I will describe our efforts to probe the distant universe via ongoing studies of Lyman alpha galaxies at z = 2 to 5. In particular, I will focus on recent measurements of their gas-phase metallicities, diagnostics of their dust attenuation and the distribution of their Lyman alpha surface brightnesses. These observations help build a complete picture of how Lyman alpha emission escapes from these galaxies, which gives us hints into how the most distant galaxies are evolving.

405 – Einstein vs Schwinger: Who is Right about Gravity? I

Meeting-in-a-Meeting – Summit Hall 4, Egan Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

For some time General Relativity, the Standard Model of Cosmology, and the Standard Model of Particle Physics have been mutually supportive. Particle physicists have always known that their model is incomplete; something else is needed â€“

perhaps the Higgs Boson and related supersymmetric particles. Early results from the Large Hadron Collider have not yet supported physics beyond the Standard Model. A hoped-for candidate for dark matter, the lightest supersymmetric particle is still missing.

The standard model of cosmology relies on Einstein, and specific values for five parameters. Yet there is a competitor to Einstein. Julian Schwinger did not like the warping of space and time. Schwingerâ€™s Source theory is a modern one that uses the general requirements of a tensor source to explain first and second-order relativistic effects, even including the precession of the perihelion of Mercury or the precession of the gyroscopes in the Gravity Probe B experiment. According to general relativity the geodetic effect in this experiment comes from the gravitational analogue of spin-orbit coupling (1/3) and from the curvature of space (2/3). Schwinger reached the same conclusion. He predicted that 4/3 rds of the geodetic effect is spin-orbit and minus 1/3 rd is Thomas Precession.

This difference is academic, but a genuine difference appears in the extensions of Einsteinâ€™s and Schwingerâ€™s theories. In 1917 Einstein extended his real theory with the cosmological constant. In contrast, the extension of Schwingerâ€™s complex theory leads naturally to a massive graviton (Newtonâ€™s potential becomes the Yukawa potential) or even a graviton of imaginary mass (Newtonâ€™s potential becomes the cosinusoidal potential). This session will explore evidence for lambda-CDM cosmology and for an alternative, the Cosinusoidal Potential, V=-GMCos[koR]/R.

Speakers: Virginia Trimble, Francis Everitt, and David Bartlett.

405.01 – **Gravity Before Einstein and Schwinger Before Gravity**

Virginia L. Trimble[1]

[1]*UC, Irvine.*

10:00 AM - 10:30 AM

Julian Schwinger was a child prodigy, and Albert Einstein distinctly not; Schwinger had something like 73 graduate students, and Einstein very few. But both thought gravity was important. They were not, of course, the first, nor is the disagreement on how one should think about gravity that is being highlighted here the first such dispute. The talk will explore, first,

several of the earlier dichotomies: was gravity capable of action at a distance (Newton), or was a transmitting ether required (many others). Did it act on everything or only on solids (an odd idea of the Herschels that fed into their ideas of solar structure and sunspots)? Did gravitational information require time for its transmission? Is the exponent of r precisely 2, or 2 plus a smidgeon (a suggestion by Simon Newcomb among others)? And so forth. Second, I will try to say something about Scwinger's lesser known early work and how it might have prefigured his "source theory," beginning with "On the Interaction of Several Electrons (the unpublished, 1934 "zeroth paper," whose title somewhat reminds one of "On the Dynamics of an

Asteroid," through his days at Berkeley with Oppenheimer, Gerjuoy, and others, to his application of ideas from nuclear physics to radar and of radar engineering techniques to problems in nuclear physics. And folks who think good jobs are difficult to come by now might want to contemplate the couple of years Schwinger spent teaching elementary physics at Purdue before moving on to the MIT Rad Lab for war work.

405.02 – **WITHDRAWN: The Discovery of Maxwell’s Equations**

C.w. Francis Everitt[1]

[1]*Stanford University.*

In January 1865, Maxwell at age 34 wrote a letter to his cousin Charles Cay describing various doings, including his work on the viscosity of gases and a visit from two of the world’s leading oculists to inspect the eyes of his dog “Spice”. He added, “I have also a paper afloat, with an electromagnetic theory of light, which, till I am convinced to the contrary, I hold to be great guns.” That paper “A Dynamical Theory of the Electromagnetic Field” was his fourth on the subject. It was followed in 1868 by another, and then in 1873 by his massive two volume Treatise on Electricity and Magnetism. We celebrate this year the 150th anniversaries of two events fundamental to astrophysics, Maxwell’s first astonished realization of the link between electromagnetism and light, and Bunsen and Kirchhoff’s creation of the science of spectroscopy. In this presentation, I address two points relevant for all of us who ponder the condition of physics today. First, Maxwell’s theory was not simply a new theory; it was a new kind of theory. Second, in each of his five main papers, he presented a complete overall view of the subject, radically different from the one before. Whether we agree or disagree with Schwinger’s effort to rearticulate Einstein’s theory, Maxwell would have considered it well worth thoughtful examination.

405.03 – **A Massive Photon and a Graviton of the same, but Imaginary Mass?**

David F. Bartlett[1], J. P. Cumulat[1]

[1]*Univ. of Colorado.*

10:30 AM - 11:00 AM

We propose that the photon has a mass of 10^{-25} eV. This mass is equivalent to a Compton wavelength of 400 pc. The potential near an isolated point charge is $\varphi_e = (Q/r)\ \mathrm{Exp}[-2\pi r/400\ \mathrm{pc}]$. Additionally the graviton has the same, but imaginary mass. Thus the potential near a point mass is $\varphi_g = -(GM/r)\ \mathrm{Cos}[2\pi r/400\ \mathrm{pc}]$.

We illustrate this hypothesis by several “divides”. The Chibisov (1976) divide (1 /400 pc) separates spatial frequencies where the vector potential A dominates from the familiar larger wavenumbers where the magnetic field B is important. The Broadhurst (1990) structure at 128 h^{-1} Mpc is the upper limit on presently observed periodic structure in ordinary matter in the universe. The Ferrarese (2002) divide at 170 km/s is the lower limit on the applicability of the V-circular sigma-central relation. The Carollo (1999) divide at at a half-light radius of 100 pc separates dwarf spheroidals from clusters of stars. The extreme disk of the MW is limited by Dame(1987) boundaries at ± 100 pc. Bright comets are captured from the Oort cloud by strong radial galactic tides, but only when their aphelia exceed the Matese (1996) divide of 20000 AU.

The corollary: we are not enthusiastic about either Dark Matter or Dark Energy. We are aware of the corollary to our corollary! (But still hope you will read our posters for details).

Ref: “Analogies between electricity and gravity”, Metrologia 41 (2004) S115-S124.

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406 – Astrophysics with Kepler - Binary Stars

Meeting-in-a-Meeting – Ballroom C, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

Kepler's precision and time coverage offer a unique opportunity for astrophysical studies of stars, from detailed analyses of individual sources, to ensemble studies at unprecedented precision. Kepler's Guest Observer program and the Kepler Asteroseismic Science Consortium offer opportunities for observers to both select targets and to collaborate on results from existing targets. Talks in the two sessions will cover asteroseismic results from stars across the HR diagram, Red Giant Oscillations, eclipsing and interacting binary stars, stellar activity and rotation, variable stars, results from non-stellar sources, and extragalactic sources.

406.01 – **Eclipsing Binaries with the Kepler Mission**

Andrej Prsa[1], Kepler Eclipsing Binary Working Group

[1]*Villanova University.*

10:00 AM - 10:15 AM

Kepler has revolutionized the eclipsing binary field by providing us essentially uninterrupted data of unprecedented quality. Out of ~160,000 targets, we detected over 2500 eclipsing binaries. These range in orbital periods from as short as 0.3 days, all the way to several years, and encompass stellar types across the H-R diagram. In this talk I will present the collaborative effort of the Kepler Eclipsing Binary Working Group to study and characterize these systems on a statistical level: their distribution in periods, galactic latitude, spectral type, fundamental stellar properties and multiplicity as evidenced by eclipse timing variations. I will further show the gems that have sprung from this sample, which were modeled and interpreted to reveal intrinsically pulsating components, runaway encounters with massive tertiaries, stellar objects that populate the lowest end of the main sequence and circumbinary planets. I will critically review and discuss the causes of data systematics and detrending, and introduce a novel algorithm to classify light curves into morphological types using Locally Linear Embedding. Finally, I will touch on the dark side of eclipsing binaries as the primary cause of false positives in extrasolar planet detections with Kepler.

406.02 – **A Catalog of Eclipse Times for Kepler Eclipsing Binaries**

Jerome A. Orosz[1]

[1]*San Diego State Univ..*

10:15 AM - 10:27 AM

The Kepler mission has provided nearly complete, high signal-to-noise light curves for more than 2000 eclipsing binaries. Using roughly 2.5 years of data, we have measured eclipse times for a subsample of the eclipsing binaries with periods greater than 0.9 days that are classified as either detached or semi-detached. The deviations of the eclipse times from a linear ephemeris can indicate the presence of a third body in the system. We will briefly describe the technique used to measure the eclipse times. We will show examples of binaries with large deviations from a linear ephemeris, binaries where the eclipse depths change owing to perturbations from a third body, and binaries with eclipses due to third bodies. We will give some basic statistical results derived from the catalog, and discuss the implications for the rate of close triple systems.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate. The author acknowledges support from the Kepler Participating Scientist Program via NASA grant NNX 08AR14G.

406.03 – **Eclipse Timing Variations of Short-Period Binaries in the Kepler Field**

Kyle E. Conroy[1], A. Prsa[1], J. Orosz[2], W. Welsh[2], Kepler team

[1]*Villanova University,* [2]*San Diego State University.*

10:27 AM - 10:39 AM

2165 eclipsing binaries in the Kepler field have been identified and characterized by Prsa et al. (2011) and Slawson et al. (2011). Due to Kepler's essentially uninterrupted observing, we are presented with an opportunity to precisely measure eclipse timings and detect any underlying signals due to third bodies, apsidal motion, dynamical interaction, etc. Orosz et al. (2012; in prep.) are focusing on eclipse timing variations of binaries with periods longer than about 1 day. For shorter period binaries, Kepler's 30 minute exposure time causes significant smearing of lightcurves and may induce spurious signal for binaries of near-commensurate periods. These effects, along with imperfections in the detrending process, can result in systematic artifacts. To compute eclipse timing variations, we fit a polynomial chain to the phased lightcurve data and slide this function across each eclipse to find the corresponding time that minimizes the residuals. We tested this method on synthetic data and apply it to Kepler data. We present statistical results on eclipse timings and discuss our findings. This project is supported through the Kepler Participating Scientist Award NSR303065.

406.04 – **Spot Migration and Pulsation in the Interacting Binary WX Draconis**

Geraldine J. Peters[1], R. E. Wilson[2]

[1]*Univ. of Southern California,* [2]*Univ. of Florida.*

10:39 AM - 10:51 AM

Kepler observations have revealed a set of short-period Algol type eclipsing binaries with unequal brightness at the quadrature phases. The relative brightness at the quadratures varies and reverses over a time scale of 100-400 days. We call these systems L/T (leading hemisphere/trailing hemisphere) variables. To the best of our knowledge such behavior has not been identified in Algols from ground-based photometry. The prototype is WX Dra (A8 + K0 IV, P = 1.80 d) which shows L/T variations of 2-3% within the observed time window of 1-2 years. Least Squares analyses of WX Dra suggest that the L/T behavior is due to a migrating hot spot on the primary star, although magnetic spot activity is not ruled out. For an adopted $T_{primary}$ of 7800 K and a spot angular radius of 0.10 radians, Kepler Long Cadence data yield: $T_{secondary}$ = 5140 K, $m_{secondary}/m_{primary}$ = 0.125, star separation = 7.9 R_{sun}, and inclination = 88.25º. The solution suggests a (presumably accretion) spot with temperature 2.3 times the primary photosphere's that migrated 40 degrees in longitude during Kepler Quarter 7. Short cadence data from November of 2010 reveal prominent δ Sct-like primary star pulsations with period 40.6 m and light amplitude of about 2%.

The authors appreciate support from NASA grant NNX11AC78G

406.05 – **Kepler and Red Giants in the Old Open Cluster NGC 6791**

Ruth Peterson[1]

[1]*Astrophysical Advances.*

10:51 AM - 11:03 AM

This work illustrates several ways in which Kepler observations obtained through our Cycle 2 and 3 GO programs are better characterizing the red giant population in NGC 6791. This metal-rich cluster is critically important both for its stellar properties and as a nearby template for old stellar systems within and beyond our Galaxy, such as the “red-and-dead” elliptical galaxies. It is a massive, old, nearby cluster with a metallicity three times solar. Its binary fraction is high, about 50% among stars on or near the main sequence.

We present a progress report on the detection of detached eclipsing binaries among giants, the primary goal of this program. We illustrate the discrimination of field non-members from true members of similar magnitude using Kepler light curves, and the results so far from our survey of potential members at large distances from the cluster center. Among the brighter stars in the sample, we relate the Kepler astroseismological signatures to spectroscopic results obtained for the same stars.

407 – Evolved Stars and Supernova Remnants

Oral Session – Room 1, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

407.01 – **Binary Effects in Mass Flow Variations in AGB Envelopes**

Hyosun Kim[1], R. E. Taam[1]

[1]*ASIAA, Taiwan.*

10:00 AM - 10:10 AM

Recent observations of strikingly well-defined spirals around asymptotic giant branch (AGB) stars point to the importance of the presence of binary companions to explain the properties of the evolved giant envelopes. In a binary system, the structure of the mass lost by an AGB star is altered (1) by modifying the distribution of the wind velocity due to the reflex motion of the AGB star and (2) by gathering a fraction of the wind material into the gravitational potential of the companion so as to create a gravitational density wake. We examine, and compare, these two effects associated with a binary companion using high-resolution three-dimensional hydrodynamical simulations. Our study on the details of density and velocity distribution of the modulated AGB wind in a simple hydrodynamic model reveals the importance of hydrodynamic effects, which were not found in previous analytic and ballistic calculations. It is found that the reflex motion of the AGB star determines the overall shape of the outflowing envelope in which the gravitational influence of the companion star is spatially restricted. Attention is focused on the morphological and kinematic properties of the circumstellar pattern as potential probes for the binary properties. In particular, we present the envelope shapes as a function of viewing inclination angle. In addition to a spiral pattern providing evidence of binary, we also emphasize the arc pattern representing the same structure viewed at different inclination angles. In particular, the arc pattern becomes spherically symmetric when the orbital motion of the AGB star is significantly slower than its wind speed. Furthermore, in comparable-mass binary systems, the gravitational wake of the companion forms clumpy shapes on the rather broader arc pattern caused by the reflex motion of the mass-losing star.

407.02 – **The Cooling and Pulsation of the White Dwarf in GW Lib after its 2007 Outburst**

Paula Szkody[1], A. S. Mukadam[1], B. T. Gaensicke[2], A. Henden[3], E. M. Sion[4], D. Townsley[5], P. Chote[6], E. J. Harpe[7], J. J. Hermes[8], D. J. Sullivan[9], D. E. Winget[8]

[1]*Univ. of Washington,* [2]*University of Warwick, United Kingdom,* [3]*AAVSO,* [4]*Villanova University,* [5]*University. of Alabama,* [6]*Victoria University, New Zealand,* [7]*Heritage High School,* [8]*Univ. of Texas,* [9]*Univ. of Victoria, New Zealand.*

10:10 AM - 10:20 AM

The dwarf nova GW Lib contains an accreting, pulsating white dwarf. The presence of dwarf nova outbursts in systems such as this enable a unique chance to study how systems move in and out of the instability strip, as the outburst heats the white dwarf and it subsequently cools (on timescales of a few years rather than millions of years as in the evolution of single white dwarfs). GW Lib had a 9 mag outburst in 2007, producing significant heating. Our ultraviolet COS spectra from HST and our ground-based coverage from a variety of telescopes during 2010-2011 reveal temperatures that are still elevated above quiescence by 1000-3000K, while a single, high amplitude pulsation near 290 sec is present during both years. This pulsation spectrum is very different from the quiescent one. Continued coverage to follow the final cooling and evolution of the spectrum to final quiescence will reveal insights into the g-mode frequencies and the accreted layer mass.

Support for this work was provided by HST grants GO-11639, GO-12231 and NSF grant AST-1008734.

407.03 – **Time-resolved Spectroscopy and Multi-color Photometry Of The Pulsating and Short-period Binary Subdwarf B Star Feige 48**

Mike Reed[1], A. Baran[1], S. O'Toole[2]

[1]*Missouri State Univ.,* [2]*Australian Astronomical Observatory, Australia.*

10:20 AM - 11:30 AM

Pulsating subdwarf B (sdB) stars can be used as probes of the helium fusing cores of horizontal branch stars. To probe these stars, asteroseismology must be able to observationally associate pulsation frequencies with modes. Time-resolved spectroscopy and multicolor photometry have been employed with mixed results for short-period pulsating sdB stars. Time-resolved spectroscopy has successfully measured radial velocity, temperature, and gravity variations in six pulsators, yet interpreting results is far from straightforward. Multicolor photometry requires extremely high precision to discern between low-degree modes, yet has been used effectively to eliminate high-degree modes. Combining RV and multicolor measurements has also been shows as an effective means of constraining mode identifications. I will present results for Feige 48 using both time-resolved spectroscopy and multicolor photometry and attempts to constrain their pulsation modes using the atmospheric codes BRUCE and KYLIE.

407.04 – **New Radio Continuum, Hi, And X-ray Observations Of The Old Supernova Remnant Ctb80**

Denis A. Leahy[1]

[1]*Univ. of Calgary, Canada.*

10:30 AM - 11:40 AM

New radio continuum and HI line observations of the old supernova remnant CTB80 are analyzed. The radio continuum emission is more extended than previously known, and a 21cm absorption line profile is produced, which gives a revised distance to the supernova remnant and associated pulsar B1951+32. Archival ROSAT PSPC pointed observations of the CTB80 region are analyzed, and reveal extended X-ray emission associated the remnant over a large (1.2 degree) region. An analysis of the HI emission using the velocity channel maps confirms the inner shell found by Koo et al. (1990). In addition, an outer slowly moving shell centered on CTB80’s center, with radius 76 arcmin and velocity 40 km/s, is found. The shell’s size and velocity are not consistent with a stellar wind origin, but have properties consistent with what is expected for a cool dense shell behind the outer shock in the cooling (snowplow) phase of a supernova remnant. It is concluded from the radio and X-ray observations, that CTB80 is a large and old supernova remnant, with a slowly expanding snowplow-phase shell and a hot interior which is still emitting X-rays.

407.05 – **A Broadband Study of the Emission from the Composite Supernova Remnant MSH 11-62**

Patrick O. Slane[1], J. P. Hughes[2], T. Temim[3], R. Rousseau[4], D. Castro[5], D. Foight[1], B. M. Gaensler[6], S. Funk[7], M. Lemoine-Goumard[4], J. D. Gelfand[8], D. A. Moffett[9], R. G. Dodson[10], J. P. Bernstein[11]

[1]*Harvard-Smithsonian, CfA,* [2]*Rutgers University,* [3]*NASA/GSFC,* [4]*Universite de Bordeaux, France,* [5]*MIT,* [6]*University of Sydney, Australia,* [7]*SLAC,* [8]*NYU Abu Dhabi,*

United Arab Emirates, [9]Furman University, [10]University of Western Australia, Australia, [11]Argonne National Laboratory.
10:40 AM - 1:50 AM

MSH 11-62 (G291.0-0.1) is a composite supernova remnant for which radio and X-ray observations have identified the remnant shell as well as its central pulsar wind nebula. The observations suggest a relatively young system expanding into a low density region. Here we present a study of MSH 11-62 using observations with the Chandra, XMM-Newton, and Fermi observatories, along with radio observations from the Australia Telescope Compact Array (ATCA). We identify a compact X-ray source that appears to be the putative pulsar that powers the nebula, and show that the X-ray spectrum of the nebula bears the signature of synchrotron losses as particles diffuse into the outer nebula. Using data from the Fermi LAT, we identify gamma-ray emission originating from MSH 11-62. With density constraints from the new X-ray measurements of the remnant, we model the evolution of the composite system in order to constrain the properties of the underlying pulsar and the origin of the gamma-ray emission.

407.06 – **On The Expansion Rate, Age, Distance, And Gamma-ray Emission Mechanism Of The Supernova Remnant G266.2-1.2**

Glenn E. Allen[1], T. DeLaney[2], M. D. Filipovic[3], J. C. Houck[1], T. G. Pannuti[4], M. D. Stage[5]

[1]MIT, [2]West Virginia Wesleyan College, [3]University of Western Sydney, Australia, [4]Morehead State University, [5]Mount Holyoke College.
10:50 AM - 11:00 AM

The age and distance of the supernova remnant G266.2-1.2 have been a source of controversy. Some report evidence of spectral line features associated with the decay of titanium-44, and, for this reason, argue that the remnant can only be a few hundred parsecs from Earth and a few hundred years old. Others find no evidence of such features and argue that the remnant is as far away as 1000-2000 parsecs (i.e. is associated with the Vela Molecular Ridge) and is thousands of years old. To address this disparity, we present the results of a comparison of Chandra X-ray data from 2003 and 2008, which suggest that the northeastern edge of the remnant is expanding at the rate of 0.43 +/- 0.09 arcsec per year. Provided that this expansion rate is representative of the remnant as a whole and provided that the remnant has not evolved beyond the Sedov-Taylor phase, hydrodynamical arguments suggest

the remnant is 1000-3000 parsecs from Earth and 2000-9000 years old. G266.2-1.2 is one of a small number of shell-type supernova remnants observed to emit TeV gamma rays. The physical process responsible for this emission is also controversial. We present the results of analyses of some ATCA radio, Chandra X-ray, and HESS gamma-ray data for the remnant. Both inverse Compton scattering and neutral-pion decay models are considered. For each model, we discuss the implied physical conditions in the remnant. Based upon these results, we argue that an inverse Compton scattering model provides a more likely description of the HESS data.

407.07 – **The Collapse Of A Massive Star: Observing SNR G296.1-0.5 With Magellan**

Daniel Castro[1], E. Helder[2], J. Raymond[3], P. Slane[3], S. Trowbridge[1]

[1]MIT Kavli Institute, [2]Pennsylvania State University, [3]Harvard-Smithsonian Center for Astrophysics.
11:00 AM - 11:10 AM

G296.1-0.5 is a bright supernova remnant that, based on recent studies, appears to be expanding into the wind of a red supergiant or Wolf-Rayet progenitor star. The composition shows unique signatures of CNO-cycle material, and the X-ray emission is suggestive of the clumpy structure expected in such winds. We present imaging and spectroscopic observations with the Inamori-Magellan Areal Camera & Spectrograph (IMACS) detector on the Magellan Baade Telescope, which explore the characteristics of the shocks and shocked medium in SNR G296.1-0.5, and hence further constrain the nature of the progenitor's late-phase mass loss, and the energetics of the explosion.

407.08 – **Flares in the Crab Nebula Driven by Untwisting Magnetic Fields**

Peter A. Sturrock[1], M. J. Aschwanden[2]

[1]Stanford Univ., [2]Lockheed Martin AdvancedTechnology Center.
11:10 AM - 11:20 AM

The recent discovery of PeV electrons from the Crab nebula, produced on rapid time scales of one day or less with a sharply peaked gamma-ray spectrum without hard X-rays, challenges traditional diffusive shock acceleration models followed by synchrotron radiation. Here we outline an acceleration model involving a DC electric field, parallel to the magnetic field, in a twisted toroidal field in the nebula.. Sudden developments of resistivity in localized regions of the twisted field are thought to drive the flares and associated particle acceleration up to PeV energies. This model can reproduce the observed time scales of about 1 day, the peak photon energies of about 1 MeV, maximum electron energies of about 1 PeV, and a luminosity of about 1036 erg s−1.

407.09 – **On Theoretical Models For Magnetic Field Amplification At Shocks**

Federico Fraschetti[1]

[1]University of Arizona.
11:20 AM - 11:30 AM

We present an MHD study supporting an explanation of the amplification of the magnetic field at the non-relativistic shocks based on dynamo effect. A realistic shock surface arbitrarily rippled is assumed. The case of quasi-perpendicular magnetic field is considered in greater detail. This result can be applied to the heliospheric shocks and to the supernova remnant shocks.

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408 – AGN, QSO, Blazars II

Oral Session – Ballroom B, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

408.01 – **The (Super Massive Black Hole)-(Host Bulge) Mass Relation**

Alister Graham[1]

[1]Swinburne Univ., Australia.
10:00 AM - 10:10 AM

Graham (2012, ApJ, v.746, article 113, "*Breaking the law: the M_{bh}-$M_{spheroid}$ relation*") is presented.

The popular, and previously thought to be log-linear, relation between super massive black hole mass, M_{bh}, and the dynamical mass of the host spheroid, M_{sph}, is reexamined in the context of achieving consistency with established galaxy scaling relations. The M_{bh}-M_{sph} relation for classical spheroids is found to be bent or curved, in agreement with expectations, and requiring an order of magnitude reduction to the mass ratio at $M_{bh} = 10^6$ M_{Sun}, such that $M_{bh}/M_{sph} = 0.025\%$. This new bent relation has important implications for black hole mass predictions in other galaxies, galaxy/black hole formation theories, evolutionary studies and more.

408.02 – **Do Agn And Non-agn Galaxies Follow The Same M-sigma Relation?**

Jong-Hak Woo[1], D. Park[1], W. Kang[1]

[1]Seoul National University, Korea, Republic of.
10:10 AM - 10:20 AM

With the revised black hole mass measurements based on new dynamical models including dark matter halos, the M-sigma relation of nearby galaxies shows much steeper slope than that of reverberation-mapped AGN sample, implying that active galaxies may have a different M-sigma relation. To investigate the origin of this discrepancy, we determine and compare the M-sigma relation of both nearby galaxy and AGN samples using new velocity dispersion measurements. First, after correcting for the rotating stellar component and aperture effects, we uniformly measured the stellar velocity dispersion for 30 objects in the nearby galaxy sample, using spatially resolved H-band spectra obtained with the Palomar Triplespec. Second, we revise the M-sigma relation of active galaxies, by including new reverberation mass and H-band stellar velocity dispersion measurements. Finally, we investigate whether various fitting methods may cause systematic difference in the slope and intrinsic scatter of the M-sigma relation. In this paper, we will present the uniformly determined M-sigma relation for AGN and non-AGN samples, and discuss whether AGN and non-AGN galaxies follow the same M-sigma relation.

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).

408.03 – **HST WFC3/IR Observations of Active Galactic Nucleus Host Galaxies at z ~ 2: Supermassive Black Holes Grow in Disk Galaxies**

Kevin Schawinski[1], E. Treister[2], C. Urry[1], C. Cardamone[3], B. Simmons[1], S. Yi[4]

[1]Yale University, [2]Universidad de Concepcion, Chile, [3]Brown University, [4]Yonsei University, Korea, Republic of.
10:20 AM - 11:30 AM

We present Hubble Space Telescope WFC3/IR imaging data on X-ray and infra-red selected AGN host galaxies at z~2 and find that a majority of them reside in galaxies whose rest-frame optical light profiles have a substantial disk component, or are even dominated by a disk. At the same time, significant disturbances indicative of ongoing major mergers are in the minority. This indicates that secular processes, and not major mergers, may be important in triggering a substantial portion of cosmic black hole growth.

KS acknowledges support by NASA through an Einstein Postdoctoral Fellowship (PF9-00069), issued by the Chandra X-ray Observatory Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of NASA under contract NAS8-03060.

408.04 – **Probing Black Hole-Host Galaxy Relations Using Dust Reddened QSOs**

Gabriela Canalizo[1], M. Wold[2], K. D. Hiner[1], M. Lazarova[1], M. Lacy[3], K. Aylor[1]

[1]Univ. of California, Riverside, [2]Dark Cosmology Centre, Univ, of Copenhagen, Denmark, [3]North American ALMA Science Center, NRAO.
10:30 AM - 11:40 AM

We describe a method to measure the M-sigma relation in dust-obscured QSOs. Since the nuclei of these objects are embedded in dust, their host galaxies are mostly uncontaminated by the blue quasar continuum, making it possible to measure from stellar absorption features at short wavelengths. At the same time, they show broad emission lines at longer wavelengths, from which black hole (BH) masses can be estimated by the virial method. We present results from a pilot sample of nine QSOs with redshifts 0.14<z<0.37. We find that there is an offset between the position of our objects and the local relation for AGN, in the sense that the majority of the red QSO hosts have lower velocity dispersions and/or more massive black holes than local galaxies. These results are in agreement with those

from recent studies of Sy1 galaxies at similar and higher redshifts. This could indicate an unusually rapid growth in the host galaxies since z~0.2. However, the z > 0.1 AGN (including our sample and those of previous studies) have significantly higher BH masses than those of local AGN, so a direct comparison is not straightforward. Further, using several samples of local and higher-z AGN, we find a striking trend of an increasing offset with respect to the local M-sigma relation as a function of AGN luminosity, with virtually all the objects with log (L5100) > 43.6 falling above the relation. Given the relatively small number of AGN at z > 0.1 for which there are measurements of stellar velocity dispersions, it is impossible at present to determine whether there truly is evolution in M-sigma with redshift. Larger, carefully selected samples of AGN are necessary to disentangle the dependence of the M-sigma relation on mass, luminosity, accretion rates, and redshift.

408.05 – **What triggers AGN? Results from Host Galaxy Studies**

Carolin Villforth[1], F. Hamann[1], A. Koekemoer[2]
[1]University of Florida, [2]Space Telescope Science Institute.
10:40 AM - 1:50 AM

We present results concerning AGN triggering in high redshift low luminosity AGN as well as local binary AGN.

408.06 – **Investigating the Gas Kinematics of High-Redshift Active Galactic Nuclei with Double-Peaked Narrow Emission Lines**

Robert S. Barrows[1], D. Stern[2], C. H. S. Lacy[1], J. Kennefick[1], D. Kennefick[1], M. Seigar[1]
[1]University of Arkansas, [2]JPL/Caltech.
10:50 AM - 11:00 AM

Pairs of supermassive black holes (SMBHs) are a natural consequence of galaxy mergers, and these systems are observable when both SMBHs are accreting as active galactic nuclei (AGN). Observational evidence for these AGN pairs (dual AGN) has dramatically increased recently through a combination of spectroscopic selection of candidates from double-peaked optical emission lines and follow-up morphological data. The primary motivation for compiling a sample of dual AGN is for their use in tracing galaxy mergers and in constraining the link between galaxy mergers and AGN enhancement. Therefore, this phenomenon should be investigated at higher redshifts when galaxy mergers were more frequent. Motivated by our detailed analysis of a candidate dual AGN at a relatively high redshift (z=1.175), we have compiled a sample of analogous sources at z>0.80 identified from double-peaked UV emission lines in the Sloan Digital Sky Survey (SDSS). The double-peaked profile can be mimicked by gas-kinematics around a single AGN, including large-scale outflows, which are known to affect the velocity profiles of high-ionization UV emission lines. Through emission line diagnostics, we have taken advantage of access to rest-frame UV emission lines in SDSS quasar spectra, allowing us to investigate the kinematics of the ionized gas. In particular, for each of these sources we have put constraints on the likelihood of a correlation between peak velocity-offset and ionization potential. Such tests will aid in determining which double-peaked emission line sources are most likely the result of an outflow and which are strong dual AGN candidates. This study will both increase the sample size of candidate dual AGN for follow-up observations and extend the sample to higher redshifts.

408.07 – **Constraining The Abundance Of Massive Black Hole Binaries By Spectroscopic Monitoring Of Quasars With Offset Broad Emission Lines**

Xin Liu[1], Y. Shen[2]
[1]Harvard College Observatory, [2]Smithsonian Astrophysical Observatory.
11:00 AM - 11:10 AM

A fraction of quasars have long been known to show significant bulk velocity offsets (of a few hundred to thousands of km/s) in the broad permitted emission lines with respect to host galaxy systemic redshift. Various scenarios may explain these features such as massive black hole binaries or broad line region gas kinematics. As previously demonstrated by the dedicated work of Eracleous and colleagues, long-term spectroscopic monitoring provides a promising test to discriminate between alternative scenarios. Here, we present a sample of ~300 shifted-line quasars homogeneously selected from the SDSS DR7. For ~60 of them, we have conducted second-epoch optical spectra using MMT/BCS, ARC 3.5m/DIS, and/or FLWO 1.5m/FAST. These new observations, combined with the existing SDSS spectra, enable us to constrain the velocity drifts of these shifted broad lines with time baselines of a few years up to a decade. Previous work has been focusing on objects with extreme velocity offsets: > 1000 km/s. Our work extends to the parameter space of smaller velocity offsets, where larger velocity drifts would be expected in the binary scenario. Our results may be used to identify strong candidates for and to constrain the abundance of massive black hole binaries, which are expected in the hierarchical universe, but have so far been illusive.

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409 – Evolution of Galaxies I

Oral Session – Room 3, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

409.01 – **Hydride Molecules in the Local Universe and Beyond**

Raquel Monje[1]
[1]Caltech.
10:00 AM - 10:10 AM

The Heterodyne Instrument for the Far-Infrared (HIFI) on board the Herschel Space Observatory (HSO) is providing invaluable data on hydride molecules in the interstellar medium within the

Milky Way and nearby galaxies. I would like to present some of the key results from hydride studies with Herschel/HIFI instrument such as the first observations at high spectral resolution of the fundamental J = 1 - 0 rotational transition of hydrogen fluoride (HF) at 1.232 THz, and the discovery of its ubiquitous nature within the ISM of the Milky Way galaxy, first detection of

some Cl-bearing molecules in diffuse medium towards a bright submillimeter continuum and the water abundance enhancement towards the Galactic Center. The data that I will present is from the guaranteed time key programs, Probing Interstellar Molecules with Absorption lines Studies (PRISMAS) and Herschel/HIFI Observations of EXtraOrdinary Sources (HEXOS).

Following-up on the Herschel discovery on molecular hydrides within the ISM of the Milky Way galaxy, we are conducting a search for the fundamental rotation lines of HF and H2O towards nearby galaxies with Herschel/HIFI and luminous lensed high-redshiftd galaxies with strong submillimeter continuum with the Caltech Submillimeter Observatory (CSO) and the Plateau de Bure Interferometer (PdBI) toward. Results and interpretation from these observations will be presented at the AAS.

409.02 – **NGC4342, An Optically Faint But X-ray Gas-Rich Early-type Galaxy**

Akos Bogdan[1], W. R. Forman[1], I. Zhuravleva[2], C. Mihos[3], R. P. Kraft[1], P. Harding[3], Q. Guo[4], E. Churazov[2], A. Vikhlinin[1], P. E. J. Nulsen[1], S. Schindler[5], C. Jones[1]
[1]Smithsonian Astrophysical Observatory, [2]Max-Planck-Institut fur Astrophysik, Germany, [3]Department of Astronomy, Case Western Reserve University, [4]Partner Group of the Max Planck Institute for Astrophysics, National Astronomical Observatories, Chinese Academy of Sciences, China, [5]Institut fur Astro- und Teilchenphysik, Universitat Innsbruck, Austria.
10:10 AM - 10:20 AM

Based on Chandra X-ray observations we studied NGC4342, an optically faint early-type galaxy, that hosts a massive black hole and an unusually bright X-ray halo. However, such a low mass galaxy should not be able to gravitationally bind a significant amount of hot gas, thereby indicating the presence of a notable dark matter halo. We investigated the origin and nature of the hot gas surrounding NGC4342, and examined which mechanisms could lead to the observed physical properties of the galaxy.

409.03 – **HI Absorption in Merger Remnants**

Stacy H. Teng[1], S. Veilleux[2], A. J. Baker[3]
[1]NASA/GSFC, [2]UMD, [3]Rutgers.
10:20 AM - 11:30 AM

It has been proposed that ultraluminous infrared galaxies (ULIRGs) pass through a luminous starburst phase, followed by a dust-enshrouded AGN phase, and finally evolve into optically bright "naked" quasars once they shed their gas/dust reservoirs through powerful wind events. We present the results of our recent 21-cm HI survey of 21 merger remnants with the Green Bank Telescope. These remnants were selected from the QUEST (Quasar/ULIRG Evolution Study) sample of ULIRGs and PG quasars; our targets are all bolometrically dominated by AGN and sample all phases of the proposed ULIRG -> IR-excess quasar -> optical quasar sequence. We explore whether there is an evolutionary connection between ULIRGs and quasars by looking for the occurrence of HI absorption tracing neutral gas outflows; our results will allow us to identify where along the sequence the majority of a merger's gas reservoir is expelled.

409.05 – **A Plausible Explanation for the Steep Redshift Decline in Barred Spirals: Dynamically Hot Disks**

Kartik Sheth[1], J. Melbourne[2], S. Kassin[3], D. M. Elmegreen[4], B. G. Elmegreen[5], E. Athanassoula[6], R. G. Abraham[7], R. S. Ellis[2], B. Weiner[8]
[1]NRAO / ALMA, [2]Caltech, [3]NASA/GSFC, [4]Vassar College, [5]IBM T.J. Watson Center, [6]LAM / OAMP, France, [7]University of Toronto, Canada, [8]University of Arizona.
10:40 AM - 10:50 AM

We present the first observational evidence for the inhibition of bar formation in dispersion dominated (dynamically hot) galaxies. We compare the presence of galactic structures (bars) and the host galaxy kinematics in a sample of ~200 disk galaxies from the All-Wavelength Extended Groth Strip International Survey (AEGIS) and the Deep Extragalactic Evolutionary Probe 2 (DEEP2) survey. We find that bars are preferentially found in galaxies that lie on the Tully-Fisher relationship and are rotation-dominated, whereas few bars are found in galaxies that are dispersion dominated. The data provide at least one explanation for the steep (x3) decline in the bar fraction from z=0 to z=0.84 previously observed in L* disk galaxies in the COSMOS field. In the COSMOS data, the decline in bars is primarily found in the low mass, late-type systems. A proposed explanation for the trend was that at higher redshifts, lower mass systems were more dispersion dominated because they were more easily harassed by the increased interaction and merger rate. The data presented here provides observational support for this hypothesis.

409.06 – **The Rotation Measure Distribution of Radio Galaxies**

Timothy Robishaw[1], A. Hammond[2], B. Gaensler[2]
[1]Dominion Radio Astrophysical Observatory, Canada, [2]The University of Sydney, Australia.
10:50 AM - 11:00 AM

Faraday rotation allows the investigation of magnetic fields along the line of sight between an observer and a polarized source. If redshifts can be measured for sources exhibiting Faraday rotation, this would allow for a direct probe of the evolution of cosmic magnetism over time scales of up to 12.5 billion years. Previous studies of rotation measure (RM) and redshift data have been hampered by the small size of available data sets (200-300 sources at most), often drawn from highly inhomogeneous observations. We present a new catalog of over 4000 extragalactic sources with both RM and redshifts. These data were compiled using large-scale surveys and new radio-optical associations, yielding a sample size that is more than an order of magnitude larger than any previous study. Our sample includes more than 1000 sources at a redshift z>1. We present a statistical analysis of our catalog, from which we find that the variance of the RM distribution, after subtraction of the RM contribution from our own Milky Way, increases slightly with redshift at a 98.5% confidence level. Further, we show that both residual RM and redshift are correlated with fractional polarization, contributing to the RM-redshift relationship.

409.07 – **Hubble Infrared Pure Parallel Imaging Extragalactic Survey (HIPPIES)**

Haojing Yan[1]

[1]*University of Missouri - Columbia.*

11:00 AM - 11:10 AM

The recent progress of the Hubble Infrared Pure Parallel Imaging Extragalactic Survey (HIPPIES) will be reported. HIPPIES utilizes the pure parallel orbits at the HST to do multi-band, deep imaging with the WFC3 and the ACS, and has been incorporating all existing, suitable parallel data since Cycle 17. Starting from the key goal of studying galaxies at very high redshifts (z>7), HIPPIES has evolved to a general purpose survey that has a wide range of science objectives. Its uniqueness is in its large number of random fields, whichminimizes the impact of "cosmic variance". A number of our science results willbe highlighted.

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410 – Solar Energetic Events I

Oral Session – Room 4, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

410.01 – **Understanding Solar Flares**

Judith T. Karpen[1], S. K. Antiochos[1], C. R. DeVore[2]

[1]*NASA GSFC,* [2]*NRL.*

10:00 AM - 10:15 AM

Solar flares and their associated coronal mass ejections are the most energetic explosions in the solar system. The largest events pose the greatest space weather dangers to life and civilization, and are of extreme importance to human space exploration. They also provide the best opportunity to study the universal processes of magnetic reconnection and particle acceleration that underlie most solar activity. The two great mysteries of solar flares are: how can so much energy be released so quickly, and how can such a large fraction (50% or more) end up in energetic particles. We present results from recent numerical modeling that sheds new light on these mysteries. These calculations use the highest spatial resolution yet achieved in order to resolve the flare dynamics as clearly as possible. We conclude from this work that magnetic island formation is the defining property of magnetic reconnection in the solar corona, at least, in the large-scale current sheet required for a solar flare. Furthermore, we discuss the types of future observations and modeling that will be required to solve definitively the solar flare mysteries.

This work was supported, in part, by the NASA TR&T and SR&T Programs.

410.02 – **Global Energetics of Large Solar Eruptive Events**

Brian R. Dennis[1], A. G. Emslie[2], P. C. Chamberlin[1], R. A. Mewaldt[3], C. S. Moore[4], G. H. Share[5], A. Y. Shih[1], A. Vourlidas[6], B. Welsch[7]

[1]*NASA's GSFC,* [2]*Department of Physics and Astronomy, Western Kentucky University,* [3]*California Institute of Technology,* [4]*Center for Astrophysics and Space Astronomy, University of Colorado,* [5]*Department of Astronomy, University of Maryland,* [6]*Code 7663, Naval Research Laboratory,* [7]*Space Sciences Laboratory, University of California.*

10:15 AM - 10:30 AM

We have evaluated the energetics of the larger solar eruptive events recorded with a variety of spacecraft instruments between February 2002 and December 2006. All of the energetically important components of the flares and of the accompanying coronal mass ejections and solar energetic particles have been evaluated as accurately as the observations allow. These components include the following: (1) the total energy in the high temperature plasma determined from the RHESSI thermal X-ray observations; (2) the total energies in accelerated electrons above 20 keV and ions above 1 MeV from RHESSI hard X-ray and gamma-ray observations, respectively; (3) the potential and kinetic energies of the CME from SOHO/LASCO observations; (4) the solar energetic particle (SEP) energy estimates from in situ measurements on ACE, GOES, and SOHO; (5) the total radiated energy from the SORCE/TSI measurements where available, and otherwise from the Flare Irradiance Spectral Model (FISM). The results are assimilated and discussed relative to the probable amount of nonpotential magnetic energy estimated to be available in the flaring active regions from MDI line-of-sight magnetograms.

410.03 – **The Focusing Optics X-ray Solar Imager (FOXSI)**

Steven Christe[1], S. Krucker[2], L. Glesener[2], S. Ishikawa[2], B. Ramsey[3], T. Takahashi[4], R. Lin[2]

[1]*NASA GSFC,* [2]*Space Sciences Lab, UC Berkeley,* [3]*NASA MSFC,* [4]*Department of Physics, University of Tokyo, Japan.*

10:30 AM - 10:45 AM

Hard x-ray (HXR) observations are a powerful diagnostic tool providing quantitative measurements of nonthermal energetic (>10 keV) electrons. Energetic electrons traveling in a plasma radiate HXR emission through the well-known process of bremsstrahlung. Solar eruptive events are the most powerful particle accelerators in the solar system, accelerating electrons up to hundreds of MeV. It is thought that the energy release process and particle acceleration occur somewhere in the corona. Since bremsstrahlung emission depends on the density of the ambient medium, solar HXR emission is strongest when electron beams enter the chromosphere where they lose their energy quickly through collisions. Energetic electrons moving in the relatively tenuous corona suffer few collisions, losing little energy and producing only faint HXR emission. Present-day instruments do not have the sensitivity to see the faint HXR emission from electrons traveling in the corona, nor the dynamic range to see such faint emission in the presence of bright HXR footpoint emission. Existing observations therefore show us only where energetic electrons are stopped but not where they are accelerated, nor along what path they escape from the acceleration site. Thus, to make the next breakthrough in understanding the energy release in solar eruptive events requires HXR imaging with much higher sensitivity and dynamic range. HXR focusing optics combined with position sensitive solid state detectors can provide both. We discuss the current state of technological development in this area and the science it would make possible.

410.04 – **Measurements of the Super-Hot Flare Component Using the Fe XXV and Fe XXVI Lines Near 1.8 Å**

George A. Doschek[1]

[1]*NRL.*

10:45 AM - 11:00 AM

The so-called magnetic reconnection region in the Standard Flare Model has not been adequately explored observationally, and theoretical predictions are difficult to make due to the complexity of the magnetic reconnection process. Observations from RHESSI and other spacecraft have indicated that many flares exhibit hot plasma that may extend up to 50 MK, producing copious hard and soft X-rays (e.g., Caspi & Lin 2010, ApJ, 725, L161). Some of this plasma must be contained in the reconnection region as well as in closed flare loops via chromospheric evaporation. In this contribution I discuss the spectroscopy of the Fe XXV and Fe XXVI multiplets near 1.8 Angstroms and how these multiplets may be used to infer physical conditions in the reconnection region that include electron temperature, departure from ionization equilibrium, non-thermal motions, bulk Doppler motions, electron density, and polarization. I also consider briefly the types of instrumentation necessary to obtain the spectral observations. I also briefly discuss the diagnostic potential of the entire X-ray spectrum from about 2 to 25 Angstroms for diagnosing physical conditions is multi-million degree flare plasmas.

410.05 – **Why an Advanced UV/EUV Imaging Spectrometer is needed to Study Energy Release in Solar Eruptive Events**

Gordon Dean Holman[1]

[1]*NASA's GSFC.*

11:00 AM - 11:15 AM

A longstanding puzzle for understanding solar flares and associated coronal mass ejections is determining when, where, how, and in what forms energy is released in these events. In the impulsive phase of flares, so much energy is found to be contained in accelerated electrons, and possibly ions as well, that heating by these nonthermal particles could explain the thermal and hydrodynamic evolution of the flare plasma. Even in the earlier and later stages of a flare, undetected accelerated particles could be responsible for energizing the plasma. However, it is likely that additional heating is occurring in all stages of the flare and CME evolution. Energy release in solar eruptive events cannot be understood without identifying all significant sources of heating throughout the events. Since most of this heated plasma radiates at UV/EUV wavelengths, observations at these wavelengths are critical.

Numerical models are now quite sophisticated and can predict the temporal and spatial evolution of flare plasma and the radiation it emits. An arbitrary heating function can be used, including heating by the accelerated electron distribution deduced from hard X-ray observations. Such modeling, along with UV/EUV and X-ray observations, will allow the presence of additional heating sources to be inferred. This requires a high-resolution UV/EUV imaging spectrometer with high cadence and dynamic range that does not saturate at flare intensities. In addition to determining the evolution of heated plasma from chromospheric to flare temperatures, such an instrument could directly detect reconnection jets and the presence of accelerated ions with energies below 1 MeV.

410.06 – **UV Spectroscopy of Coronal Mass Ejections**

John C. Raymond[1], N. A. Murphy[1], A. Ciaravella[2]

[1]*Harvard-Smithsonian, CfA,* [2]*INAF-Osservatorio Astronomico di Palermo, Italy.*

11:15 AM - 11:30 AM

Spectroscopy at UV and EUV wavelengths provides unique information about the physical parameters of CMEs, including the line-of-sight velocity, the elemental composition, the charge distributions of different elements, the densities, the proton temperatures and the turbulent velocities. They also provide these

parameters for the pre-eruption corona, perhaps most importantly constraining the presence of a seed particle population for Solar Energetic Particles. These quantities can be used to understand the physical processes at work, including reconnection in current sheets, energy dissipation in collionless shock wavesand continued heating of the plasma after it leaves the erupting region. With improved spectral range and sensitivity, it will be possible to discriminate among theories of magnetic reconnection, to determine the parameters of theoretical models of particle acceleration in shocks, and to pin down the nature of a significant term in the energy budget -- the post eruption heating of CME plasma.

411 – Coronal B Fields II

Oral Session – Room 5, Dena'ina Center – 6/13/2012 10:00:00 AM to 6/13/2012 11:30:00 AM

411.01 – **Are Polar Field Magnetic Flux Concentrations Responsible for Missing Interplanetary Flux?**

Jon A. Linker[1], C. Downs[1], Z. Mikic[1], P. Riley[1], C. J. Henney[2], C. N. Arge[2]

[1]*Predictive Science Inc,* [2]*Air Force Research Laboratory.*

10:00 AM - 10:15 AM

Magnetohydrodynamic (MHD) simulations are now routinely used to produce models of the solar corona and inner heliosphere for specific time periods. These models typically use magnetic maps of the photospheric magnetic field built up over a solar rotation, available from a number of ground-based and space-based solar observatories. The line-of-sight field at the Sun's poles is poorly observed, and the polar fields in these maps are filled with a variety of interpolation/extrapolation techniques. These models have been found to frequently underestimate the interplanetary magnetic flux (Riley et al., 2012, in press, Stevens et al., 2012, in press) near the minimum part of the cycle unless mitigating correction factors are applied. Hinode SOT observations indicate that strong concentrations of magnetic flux may be present at the poles (Tsuneta et al. 2008). The ADAPT flux evolution model (Arge et al. 2010) also predicts the appearance of such concentrations. In this paper, we explore the possibility that these flux concentrations may account for a significant amount of magnetic flux and alleviate discrepancies in interplanetary magnetic flux predictions.

Research supported by AFOSR, NASA, and NSF.

411.02 – **Evolution of Coronal Relative Magnetic Helicity and Current Helicity in NOAA Active Region 11158**

Ju Jing[1], S. Park[2], C. Liu[1], T. Wiegelmann[3], Y. Xu[1], N. Deng[1], H. Wang[1]

[1]*New Jersey Institute of Technology,* [2]*Korea Astronomy and Space Science Institute, Korea, Republic of,* [3]*Max Planck Institut f""ur Sonnensystemforschung (MPS), Germany.*

10:15 AM - 10:30 AM

The evolution of relative magnetic helicity contained in an active region is a crucial ingredient to describe the complexity in solar atmosphere. In this paper we present the temporal evolution of relative magnetic helicity (Hr) in NOAA active region 11158 during a 4-day period of February 12-15, 2011. The photospheric vector magnetograms of the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamic Observatory (SDO) are used as the boundary conditions to extrapolate the three-dimensional (3D) non-linear force-free (NLFF) coronal magnetic field, based on which Hr inside the 3D coronal volume is deduced. A bump pattern in Hr prior to two major flares is noted and may be a precursor of major flares. We compare the temporal variation of Hr with that of the accumulated amount of helicity injected through the photosphere that is inferred independently by tracking the apparent motion of magnetic footpoints at the photosphere from a line-of-sight HMI magnetogram series. The good consistency between Hr and the injected helicity suggests that the helicity is generated largely below the photosphere and is well conserved from the subsurface into the corona. In addition, the altitude-time diagram of the average unsigned current helicity displays a clear propagation pattern over two days prior to the X2.2 flare of February 15, with an average propagation rate of~36 m/s. The propagation is synchronous with the emergence of magnetic flux, and indicative of a gradual energy buildup for the flares.

411.03 – **Force-Free Magneto-Stereoscopy of Coronal Loops**

Markus J. Aschwanden[1], A. Malanushenko[1], J. Wuelser[1], N. Nitta[1], J. R. Lemen[1], M. DeRosa[1]

[1]*Lockheed Martin ATC.*

10:30 AM - 10:45 AM

We derive an analytical approximation of nonlinear force-free magnetic field solutions (NLFFF) that can efficiently be used for fast forward-fitting to solar magnetic data, constrained either by observed line-of-sight magnetograms and stereoscopically triangulated coronal loops, or by 3D vector-magnetograph data. We test the code by forward-fitting to simulated data, to force-free solutions derived by Low and Lou (1990), and to active regions observed with STEREO/EUVI and SOHO/MDI. The forward-fitting tests demonstrate: (i) a satisfactory convergence behavior (with typical misalignment angles of 1-10 deg), (ii) a high fidelity of retrieved force-free alpha-parameters, and (iii) relatively fast computation times (from seconds to minutes). The novel feature of this NLFFF code is the derivation of a quasi-forcefree field based on coronal constraints, which bypasses the non-forcefree photosphere of standard magnetograms. Applications range from magnetic modeling of loops to the determnination of electric currents, twist, helicity, and free (non-potential) energy in active regions.

411.04 – **Topology of Coronal Fields from Evolving Magnetofrictional Models**

Marc L. DeRosa[1], M. Cheung[1]

[1]*Lockheed Martin.*

10:45 AM - 11:00 AM

The evolving magnetofrictional (MF) scheme enables the construction of time-dependent models of the active region coronal magnetic field in response to photospheric driving. When advancing such models, only the magnetic induction is solved, during which the velocity at each point is assumed to be oriented parallel to the Lorentz force. This leads to the field to evolve toward a force-free state. We present results from an evolving MF model of NOAA AR11158 using driving from time sequences of SDO/HMI data. Utilizing this simulation, we

investigate changes in magnetic configurations and topology, including the number of null points, evolution of quasi-separatrix layers, and the time-history of total and free magnetic energies as well as relative helicity. This work seeks to elucidate the relation(s) between topological and energetic properties of the AR.

411.05 – **The Effect of Flux Cancellation on Building Sigmoidal Flux Ropes**

Antonia Savcheva[1], L. Green[2], A. van Ballegooijen[3], E. DeLuca[3]

[1]*Boston Univ.,* [2]*Mullard Space Science Laboratory, University College London, United Kingdom,* [3]*Harvard-Smithsonian Center for Astrophysics.*

11:00 AM - 11:15 AM

The magnetic structure of sigmoidal active regions is generally associated with the presence of a twisted flux rope held down by a potential arcade. There are competing theories of how the flux rope develops - by flux emergence, cancellation, or footpoint motions. We look at how flux cancellation in several sigmoidal regions, observed with XRT, affects the buildup of the underlying flux ropes. We use MDI magnetograms to quantify the flux cancellation, and the flux rope insertion method to construct non-linear force free field models of the regions. These models allow us to produce 3-D magnetic field models and see how the fields evolve in time. The models show how the flux ropes energy and magnetic flux changes during the different stages in the flux cancellation. Flux cancellation events are associated with build up of twist in the region in accordance with the accepted flux cancelation picture. The location of flares and build-up of free energy is well correlated with flux cancellation events.

411.06 – **Full Surface Automated Coronal Hole Detection and Characterization to Constrain Global Magnetic Field Models**

Chris Lowder[1], J. Qiu[1], R. Leamon[1], Y. Liu[2]

[1]*Montana State University,* [2]*Stanford University.*

11:15 AM - 11:30 AM

One of the primary mission goals of the Solar Terrestrial Relations Observatory (STEREO) : Extreme Ultraviolet Imager (EUVI) is to provide full extreme-ultraviolet (EUV) coverage of the solar surface in conjunction with the Solar and Heliospheric Observatory (SOHO) : Extreme Ultraviolet Imaging Telescope (EIT) or the Solar Dynamics Observatory (SDO) : Atmospheric Imaging Assembly (AIA). Now, five years after launch, sufficient orbital separation has occurred for this to come to fruition. Using EUV images from STEREO:EUVI in 195Å and SDO:AIA in 193Å, we can create full surface maps of coronal holes. Our method employs an intensity thresholding technique in conjunction with line-of-sight magnetic field measurements to automatically distinguish coronal holes from filament channels. This full surface coverage provides a unique opportunity to compare observed coronal holes with the predicted open magnetic field regions from both potential field models in addition to non-potential models. Our method is able to detect and characterize both long-term coronal hole structures, as well as shorter lived, transient coronal holes.

Here, this method is described in detail, with comparisons drawn between observed coronal hole boundaries and open-field boundaries derived from models. In addition, quantities that are crucially dependent on these boundaries are considered, namely the open magnetic flux.

412 – Warner Prize: Bubble, Bubble, Toil, And Trouble: A Theorist's Romp Through The Cosmic Dawn

Invited Session – Ballroom B, Dena'ina Center – 6/13/2012 11:40:00 AM to 6/13/2012 12:30:00 PM

412.01 – **Bubble, Bubble, Toil, And Trouble: A Theorist's Romp Through The Cosmic Dawn**

Steven R. Furlanetto[1]

[1]*UCLA.*

11:40 AM - 12:30 PM

The “Cosmic Dawn” is one of the most exciting frontiers of cosmology. It contains the birth of true complexity, with the advent of luminous stars and black holes, and “reionization,” a landmark event affecting every baryon in the Universe. So far its study has been primarily theoretical, but over the next decade we expect a wide variety of new telescopes to probe this important epoch. What will we see, and what can we hope to learn? I will describe some of the fundamental theoretical

principles and tantalizing observational clues guiding our expectations of this era, as well as some of the innovative observational strategies being formulated to study it.

413 – WGLE Town Hall

Town Hall – Ballroom C, Dena'ina Center – 6/13/2012 12:45:00 PM to 6/13/2012 1:45:00 PM

The Working Group on LGBTIQ Equality (WGLE) is tasked with promoting equality for lesbian, gay, bisexual, transgender, intersex, and questioning (LGBTIQ) individuals within our profession. Its goals include the elimination of workplace discrimination and inequalities in pay and benefits. This town hall will explore the anti-discrimination practices, workplace climate, and pay and benefit policies in four employment sectors: industry, the federal government, private colleges, and public universities. Presentations will be given by Rolf Danner (Northrop Grumman Aerospace Systems), Jane Rigby (Goddard Space Flight Center), Steve Lawrence (Hofstra University), and Scott Gaudi (Ohio State University), and time will be provided for comments and questions from the audience.

414 – Bridging Laboratory and Astrophysics: Planetary

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying planetary science processes which drive our cosmos.

414.01 – **Far-ultraviolet Spectroscopy of the Atmospheres of Planets, Satellites, and Comets**

Paul D. Feldman[1]

[1]*Johns Hopkins Univ..*

2:00 PM - 2:30 PM

During the past few decades, high resolution spectroscopy of the atmospheres of planets, planetary satellites, and comets, using primarily the Hubble Space Telescope and the Far Ultraviolet Spectroscopic Explorer, has produced a wealth of new information about the physical environment of these bodies. Interpretation of these spectra requires not only proper wavelengths for identification but also detailed atomic and molecular data to assess the excitation processes that lead to the observed spectral signatures. In many cases the observations have stimulated laboratory and theoretical investigations while in others the understanding of the spectra has benefited from recent independent laboratory work. This talk will present several illustrative examples and address some currently outstanding issues.

414.02 – **Modeling Atmospheres of Brown Dwarfs and Extrasolar Giant Planets**

Ivan Hubeny[1]

[1]*University of Arizona.*

2:30 PM - 3:00 PM

A brief review of spectroscopic studies of subsolar mass objects, namely brown dwarfs and extrasolar giant planets, is given, with emphasis on physics and chemistry of their atmospheres, their predicted spectra, and a comparison of theory with observations. Besides mentioning some recent highlights, main emphasis is given to discussing the role of uncertainties in the molecular opacity data, cloud formation physics, and departures from chemical equilibrium, on model atmospheres and theoretical spectra, and consequently on deducing basic physical properties of these objects.

414.03 – **Laboratory Analyses Of Samples Returned From a Comet, an Asteroid and The Sun**

Donald E. Brownlee[1]

[1]*Univ. of Washington.*

3:00 PM - 3:30 PM

Over the last decade, missions flown by the United States and Japan have returned samples from a comet that formed beyond Neptune, samples of an asteroid that crosses the Earth’s orbit and atoms from the Sun carried in the solar wind. The returned samples are being studied by a global array of state-of-the-art instrumentation that includes synchrotrons, atomic resolution electron microscopes, specialized mass spectrometers and unique instruments developed specifically for returned samples. These three missions have obtained profound sample-derived information at levels of detail that could not be obtained by either remote sensing or in situ methods. The Stardust mission showed that the rocky parts of the comet were not the expected pre-solar grains from the interstellar medium but were instead materials that formed in the inner solar system at temperatures in the 1400 K to 2200 K range. The mission provided proof of pervasive large-scale radial transport of solids in the inner regions of the solar nebula to its outer boundary. The Hayabusa mission collected dust grains from a near-earth asteroid and provided direct insight into the nature of “space weathering processes” and provided the first definitive link between an asteroidal spectral reflectance type and a specific meteorite class. The Genesis mission accurately determined isotopic composition of solar oxygen and nitrogen. The results show that all other solar system bodies are remarkably enriched in the heavy isotopes of these two elements due to remarkable and fundamental processes that occurred in the early solar system.

415 – Wide-Field IR Space Telescope Science: Mission Capabilities

Meeting-in-a-Meeting – Summit Hall 3, Egan Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

The Astro2010 Decadal Survey gave its highest recommendation in the large-scale space mission category to WFIRST, a Wide-Field Infrared Survey Telescope with both imaging and spectroscopy capabilities. The science made possible by such a facility reaches across many disciplines from dark energy to exoplanets to deep surveys. The Interim Design Reference Mission (IDRM) configuration of the observatory has a 1.3m aperture telescope in an off-axis TMA design. The focal plane has imaging and spectroscopy channels using HgCdTe detectors. The wavelength range is 0.6 - 2.0 microns. The design of observatory and operations plan will be discussed in this session.

415.01 – **WFIRST Observatory Performance**

Jeffrey Kruk[1]

[1]*NASA - GSFC.*

2:00 PM - 2:30 PM

The WFIRST observatory will be a powerful and flexible wide-field near-infrared facility. The planned surveys will provide data applicable to an enormous variety of astrophysical science. This presentation will provide a description of the observatory and its performance characteristics. This will include a discussion of the point spread function, signal-to-noise budgets for representative observing scenarios and the corresponding limiting sensitivity. Emphasis will be given to providing prospective Guest Observers with information needed to begin thinking about new observing programs.

415.02 – **WFIRST Science Requirements Flowdown and Integrated System Modeling**

Michael D. Seiffert[1]

[1]*JPL.*

2:30 PM - 3:00 PM

The Wide Field Infrared Survey Telescope (WFIRST) comprises hardware that will perform imaging and spectroscopic near-infrared sky surveys. The surveys will be applicable to a wide range of astrophysical problems; the most challenging performance requirements come from the dark energy and exoplanet observing programs. I will describe the connection between WFIRST scientific requirements and the resulting requirements on the system hardware. In the course of the definition phase, the WFIRST hardware has been the subject of an extensive design and integrated modeling effort. I will describe the integrated modeling effort as an illustration of the design considerations and tradeoffs necessary to reach the ambitious science survey goals.

415.03 – **WFIRST as an Observatory**

George Helou[1]

[1]*Caltech.*

3:00 PM - 3:30 PM

The astronomical community's interfaces with WFIRST will be designed to optimize science productivity, and will be driven by the predominantly survey-like character of the mission. In the most likely scenario, time will be allocated for (1) core surveys with teams selected through peer review to conduct science with those surveys; (2) ancillary surveys, also competed to maximize additional science; and (3) General Observer programs, allowing for targeted investigations of smaller scope.

Science support for the community will include the generation and dissemination of data products at various levels of refinement through a central archive, with additional specialized products delivered by the core survey teams and distributed through the same archive. Substantial archival research using these data is expected, and will be supported.

416 – Galaxy Mergers from the Largest to the Smallest Scales: Binary SMBHs and SMBH Coalescence

Meeting-in-a-Meeting – Room 2, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

This session focuses on SMBH binaries and their final coalescence. In these systems, the SMBHs are bound together at separations typically ~ 1 pc or smaller; at late times, the binaries coalesce to form a single SMBH due to gravitational wave emission. We open with an observational talk on candidate SMBH binaries. We then examine the astrophysics of gravitational wave emission from SMBH binaries with orbital periods of ~ years, and SMBH binaries undergoing final coalescence. We also survey possible electromagnetic emission that may be triggered by SMBH binaries and their coalescence.

416.01 – **SMBH Binaries - candidates and electromagnetic signatures**

Fukun Liu[1]

[1]*Peking University, China.*

2:00 PM - 2:20 PM

Supermassive black hole binaries (SMBHBs) are the products of galaxy mergers. The strong gravitational wave radiations emitting by compact and/or coalescing SMBHBs are the main targets of the Laser Interferometer Space Antenna (LISA) and the ongoing gravitational wave detection program Pulsar Timing Array (PTA). Because gravitational wave radiation loud SMBHBs in galactic nuclei are spatially unresolved by present telescopes, a unique electromagnetic signature is essential in locating the gravitational-wave-radiation sources. When SMBHBs form in gas-rich systems or active galactic nuclei (AGNs), the SMBHs are luminous by accreting gas from environments. Some observations of AGNs have been attributed either to the evolution of SMBHBs or to the interaction of binary SMBHs and accretion disks, including the double-double radio galaxies, X-shaped radio galaxies, helical radio jets, variations of jet precessions, and periodic variability of blazars. In the first part of my talk, I will talk about the candidates for SMBH binaries in AGNs and discuss the possible physics processes to form the observations. SMBH binaries forming at nearby gas-poor galactic nuclei are strong potential gravitational wave sources for PTAs and LISA but are dormant in electromagnetic radiation. A dormant SMBH in normal galactic nuclei could be temporarily activated by tidally disrupting a star. In the second part of my talk, I will show that the stellar tidal disruption rates are be significantly changed and the tidal flare light curves of SMBH binaries are interrupted by SMBHBs, which show unique features with information of SMBHBs and can be utilized to probe the gravitational-wave-loud SMBHBs in X-ray, UV, optical, and probably radio wavebands.

416.02 – **Binary Super-Massive Black Holes, Gravitational Waves, and Pulsar Timing Arrays**

Fredrick Jenet[1]

[1]*Univ. of Texas at Brownsville.*

2:20 PM - 2:40 PM

Binary super-massive black holes undergoing their final coalescence can generate large amplitude, low-frequency, gravitational waves. Radio pulsar timing arrays are well suited to detect and study this low frequency gravitational wave radiation. This talk will review the current status of the international efforts to detect and study gravitational waves using observations of radio pulsars. We will also discuss the current and future constraints that these observations place on the population of supermassive black holes binary systems.

416.03 – **Going Out with a Bang: Gravitational Waves from Coalescing SMBHs**

Tyson Littenberg[1]

[1]*GSFC/UMD.*

2:40 PM - 3:00 PM

Mergers of SMBH binaries are thought to the ``loudest'' emitters in the gravitational wave sky. These singularly powerful events are the keystone sources for proposed space-based gravitational wave detectors, including the ESA-led New Gravitational wave Observatory (NGO), and serve as unique probes of massive black hole astrophysics. The measurement capabilities of space-based gravitational wave detectors are unparalleled in comparison to traditional electromagnetic observations, and will play a crucial role in fully understanding galaxy mergers.

This talk will illustrate how the catalog of NGO observations will place strict constraints on scenarios for massive black hole formation and growth, while individual merger events will serve as unique laboratories for testing General Relativity.

416.04 – **Electromagnetic Signatures of SMBH Coalescence**

Jeremy Schnittman[1]

[1]*NASA/GSFC.*

3:00 PM - 3:20 PM

When two supermassive black holes (SMBHs) approach within 1-10 mpc, gravitational wave (GW) losses begin to dominate the evolution of the binary, pushing the system to merge in a relatively small time. During this final inspiral regime, the system will emit copious energy in GWs, which should be directly detectable by pulsar timing arrays and space-based interferometers. At the same time, any gas or stars in the immediate vicinity of the merging SMBHs can get heated and produce bright electromagnetic (EM) counterparts to the GW signals. We present here a number of possible mechanisms by which simultaneous EM and GW signals will yeild valuable new information about galaxy evolution, accretion disk dynamics, and fundamental physics in the most extreme gravitational fields.

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417 – Lyman Alpha Emitters as Probes of Galaxy Formation and Cosmology: Their Place in the High-redshift Galaxy Zoo

Meeting-in-a-Meeting – Summit Hall 2, Egan Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

Three 20+5 minute talks will be given comparing Lyman Alpha Emitters (LAEs) to the other denizens of the high-redshift galaxy zoo, including Lyman break galaxies (LBGs), Distant red galaxies (DRGs), BzK-selected galaxies, and Sub-millimeter galaxies (SMGs). After correcting for the biases of various observational selection techniques, these populations reveal significant overlap along with differences in typical star formation rates, stellar masses, dark matter halo masses, dust content, and morphologies. The session will conclude with a 15-minute moderated discussion of outstanding questions and how to resolve them.

417.01 – **Lyman Alpha Emitters as Tracers of Young Galaxies**

Lennox Cowie[1]

[1]*Univ. of Hawaii, Institute for Astronomy.*

2:00 PM - 2:25 PM

In studying very high redshifts we only have two diagnostics: the UV continuum and the Lyman alpha emission line. The fraction of Lyman alpha emitters (LAEs) relative to UV-continuum sources has been suggested as a potential diagnostic of the evolution in the properties of the intergalactic gas. However, our understanding of the mechanisms governing the escape of Lyman alpha photons from galaxies is poor. I will discuss recent low redshift studies which allow us to study the properties of the LAES in great detail and which have found that many LAEs are drawn from young and low-metallicity galaxies which represent early stages in the galaxy formation process. These results give us powerful insights into how galaxies form. They also suggest that a high fraction of galaxies will be LAEs at very high redshifts.

417.02 – **Lyman Alpha Emitters as Formation Sites for Globular Clusters**

Bruce Elmegreen[1]

[1]*IBM Research Div..*

2:25 PM - 2:50 PM

In the morphological mix of galaxies at high redshift, LAEs stand out as relatively numerous and low mass with high specific star formation rates. They may have a role in forming and delivering globular clusters to present-day galaxy halos. The properties of LAEs that are relevant to cluster formation will be reviewed. The same giant clumps that are likely to form massive clusters should also allow Lyman alpha photons to leak out.

417.03 – **The Physical Nature of Lyman Alpha Emitters**

Viviana Acquaviva[1]

[1]*Rutgers, The State University of New Jersey.*

2:50 PM - 3:15 PM

A galaxy’s spectrum contains information about its physical properties, such as redshift, stellar population age, mass, star formation rate, dust content, and metallicity. Multi-wavelength observations allow us to recover some of these properties through spectral energy distribution fitting. I will discuss the picture of Lyman Alpha Emitters that emerges from this process, compare LAEs to other classes of high-redshift galaxies, and take a look at their evolution through cosmic time.

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418 – Einstein vs Schwinger: Who is Right about Gravity? II

Meeting-in-a-Meeting – Summit Hall 4, Egan Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

For some time General Relativity, the Standard Model of Cosmology, and the Standard Model of Particle Physics have been mutually supportive. Particle physicists have always known that their model is incomplete; something else is needed â€“ perhaps the Higgs Boson and related supersymmetric particles. Early results from the Large Hadron Collider have not yet

identified physics beyond the Standard Model. A hoped-for candidate for dark matter, the lightest supersymmetric particle has yet to be obseved.

The Standard Model of Cosmology relies on both dark matter and dark energy. Can it be maintained without either?

Dark matter apparently is needed to bind clusters of galaxies and explain flat rotation curves. What must the characteristics of this dark matter be? Why is dark matter not everywhere, or is it? Are there plausible dark matter candidates? Is modified Newtonian Dynamics (MOND) viable?

Speakers: Nicholas Suntzeff, Kimball Milton, and Stacy McGaugh

418.01 – **TBD**

Nicholas B. Suntzeff[1]

[1]*Texas A&M University.*

2:00 PM - 2:30 PM

Nick Suntzeff "Einstein v. Schwinger" Meeting-in-a-Meeting Abstract To Be Submitted

418.02 – **Schwinger's Approach to Einstein's Gravity**

Kim Milton[1]

[1]*Oklahoma University.*

2:30 PM - 3:00 PM

Albert Einstein was one of Julian Schwinger's heroes, and Schwinger was greatly honored when he received the first Einstein Prize (together with Kurt Godel) for his work on quantum electrodynamics. Schwinger contributed greatly to the development of a quantum version of gravitational theory, and his work led directly to the important work of (his students) Arnowitt, Deser, and DeWitt on the subject. Later in the 1960's and 1970's Schwinger developed a new formulation of quantum field theory, which he dubbed Source Theory, in an attempt to get closer contact to phenomena. In this formulation, he revisited gravity, and in books and papers showed how Einstein's theory of General Relativity emerged naturally from one physical assumption: that the carrier of the gravitational force is a massless, helicity-2 particle, the graviton. (There has been a minor dispute whether gravitational theory can be considered as the massless limit of a massive spin-2 theory; Schwinger believed that was the case, while Van Dam and Veltman concluded the opposite.) In the process, he showed how all of the tests of General Relativity could be explained simply, without using the full machinery of the theory and without the extraneous concept of curved space, including such effects as geodetic precession and the Lense-Thirring effect. (These effects have now been verified by the Gravity Probe B experiment.) This did not mean that he did not accept Einstein's equations, and in his book and full article on the subject, he showed how those emerge essentially uniquely from the assumption of the graviton. So to speak of Schwinger versus Einstein is misleading,

although it is true that Schwinger saw no necessity to talk of curved spacetime. In this talk I will lay out Schwinger's approach, and the connection to Einstein's theory.

418.03 – **Galactic Rotation and Natural Law**

Stacy S. McGaugh[1]

[1]*Univ. of Maryland.*

3:00 PM - 3:30 PM

There exist a number of striking empirical regularities in the kinematics of rotating galaxies. These include flat rotation curves, the Tully-Fisher relation, and a relation between gravitational force and baryonic surface density. I suggest that these may be tantamount to Natural Laws, analogous to Kepler's Laws. The physical interpretation of these Laws is fraught with peril.

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419 – Astrophysics with Kepler - Stellar Structure

Meeting-in-a-Meeting – Ballroom A, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

Kepler's precision and time coverage offer a unique opportunity for astrophysical studies of stars, from detailed analyses of individual sources, to ensemble studies at unprecedented precision. Kepler's Guest Observer program and the Kepler Asteroseismic Science Consortium offer opportunities for observers to both select targets and to collaborate on results from existing targets. Talks in the two sessions will cover asteroseismic results from stars across the HR diagram, Red Giant Oscillations, eclipsing and interacting binary stars, stellar activity and rotation, variable stars, results from non-stellar sources, and extragalactic sources.

419.01 – **Stellar Astrophysics with Kepler from an Extended Mission Baseline**

Martin D. Still[1]

[1]*NASA Ames Research Center.*

2:00 PM - 2:15 PM

Kepler in an extended mission phase will continue to collect regular cadence time-series photometry across its one science field for some years beyond the nominal shutdown date of Nov 12, 2012. Primary science goals will continue to be the identification of Earth-sized exoplanets and the abundance of Earth-like analogs in the Galaxy. Continued spacecraft operations also opens new windows of opportunity for stellar astrophysics. An extended mission will continue to push out the boundaries of what is measurable in the areas of asteroseismology, active stars, gyrochronology and binary stars. With all Kepler data being delivered to the public archive without proprietary period, continued improvements in archived product and the support of open source software, the future of stellar astrophysics with Kepler promises to be rich. The data archive remains full of untapped potential, waiting for a new, larger wave of community participation.

419.02 – **Ensemble Asteroseismology: How Kepler is Changing Stellar Astrophysics**

Sarbani Basu[1]

[1]*Yale University.*

2:15 PM - 2:27 PM

Asteroseismic data from NASA's Kepler mission has revolutionized stellar astrophysics. These data allow us to peer inside a star and determine its internal properties and thus allow us to test different aspect of stellar evolution. The Kepler Asteroseismic Science Consortium (KASC) undertook a survey of solar type stars and detected solar-like oscillation is more than 500 stars. About 100 of these stars are still being monitored in order to do detailed seismic studies. Additionally, we have data on red giants in two clusters NGC 6819 and NGC 6791. The observations of these stars give us an unprecedented opportunity to study the ensemble properties of stars as well as properties of stars across the HR diagram. In this talk I shall discuss some of the interesting results that we have obtained so far. These include, for example, the consequence of using the solar mixing length in modelling stars.

419.03 – **A Survey of Surveys of the Kepler Field**

Steve B. Howell[1]

[1]*NASA ARC.*

2:27 PM - 2:39 PM

I will present a summary of the many ground and space based surveys recently completed or soon to be performed of the Kepler field of view. These multi-filter and multi-wavelength surveys cover varying amounts of the Kepler field and to varying depths. A discussion of the survey products available and how to get them as well as some specifics about each survey will be presented.

419.04 – **Studying the Evolution of Stars (and their Planets) beyond the Helium Core Flash via Kepler Asteroseismology**

Steven D. Kawaler[1]

[1]*Iowa State Univ..*

2:39 PM - 2:51 PM

Our understanding of what happens to stars like our Sun after they ignite helium in their cores is incomplete. Asteroseismology has proven to be a revealing probe of the structure and evolution of post helium flash stars such as hot subdwarf B stars and white dwarfs. In particular, Kepler data on pulsating sdB stars and white dwarfs (as well as RR Lyra stars) has rewritten how we study these stars. Time-series photometry has also revealed strong evidence for planets around some of these stars, raising fascinating questions about the fate of planetary systems.

419.05 – **Kepler Observations and Asteroseismology of θ Cyg, the Brightest StarObservable in the Kepler Field of View**

Joyce A. Guzik[1], G. Houdek[2], W. J. Chaplin[3], D. Kurtz[4], R. L. Gilliland[5], F. Mullally[6], J. F. Rowe[6], M. R. Haas[7], S. T. Bryson[7], M. D. Still[8]

[1]*LANL,* [2]*Institute of Astronomy, University of Vienna, Austria,* [3]*University of Birmingham, United Kingdom,* [4]*University of Central Lancashire, United Kingdom,* [5]*STScI,* [6]*SETI Institute/NASA Ames Research Center,* [7]*NASA Ames Research Center,* [8]*NASA Ames Research Center/Bay Area Environmental Research Insitute.*

2:51 PM - 3:03 PM

θ Cyg (13 Cyg) is an F4 main sequence star that, at visual magnitude V=4.48, is the brightest star observable by the Kepler spacecraft. Short-cadence photometric data using a custom aperture requiring 1800 pixels were obtained for this star during Quarter 6 (June-Sept 2010) and Quarter 8 (Jan-March 2011).

We present analyses of the solar-like oscillations first discovered in the Q6 data [1, 2]. We use observational constraints from the literature and recent ground-based observations including angular diameters from optical interferometry in conjunction with the frequency data to derive stellar properties (e.g., mass, age, metallicity, extent of convection zones). We also discuss the prospects for detecting longer period gravity-mode pulsations as seen in gamma Doradus variable stars of spectral type A-F, given these constraints.

With an effective temperature near 6500 K and near ‘solar’ element abundances, θ Cyg is near the red edge of the gamma Doradus instability strip, where high-order gravity-mode pulsations with periods of ~1 day may be present. If the envelope convection zone of the star is not too deep, these gravity-mode pulsations may be driven by the convective blocking mechanism. The calculated envelope convection

zone depth depends on the element abundance mixtures adopted for the stellar models [2]. Asteroseismic studies of θ Cyg therefore have potential to shed light on the solar abundance problem [3, 4], as well as to put constraints on the presence and detectability of g-mode pulsations for main-sequence solar-like stars.

References:

[1] Haas, M.R. et al. 2011, BAAS, 43, No. 2, 140.07.

[2] Guzik, J.A. et al. 2011, in Resolving the Future of Astronomy with Long Baseline Interferometry, Soccoro, NM,

March 2011, ASP, in press.

[3] Guzik, J.A. and Mussack, K. 2010, ApJ 713, 1108.

[4] Basu, S. and Antia, H.M. 2008, Phys. Rep. 457, 217.

419.06 – **Ultracool dwarfs in the Kepler field**

Eduardo L. Martin[1], R. Tata[2], E. Martioli[3], S. Hodgkin[4]

[1]INTA-CSIC Centro de Astrobiologia, Spain, [2]Instituto de Astrofísica de Canarias, Spain, [3]CFHT, [4]IoA, United Kingdom.

3:03 PM - 3:15 PM

Ultracool dwarfs with spectral type M7 and later include very low-mass stars as well as brown dwarfs. Due to their intrinsic faintness, only 9 very low-mass dwarfs are actually being monitored by the Kepler mission. We present light curves for some of these dwarfs that show rotational modulation due to cool spots on the surface and flare outbursts. 32 additional late-M and L dwarfs have been identified by us in the Kepler field and we have proposed to observe them during Kepler GO Cycle 4. We have selected these additional dwarfs using multi-wavelength photometric data as well as low-resolution spectroscopy for a subset of them.

The unique combination of high photometric accuracy and continuous light-curves provided by Kepler can be used to address the following scientific goals: (1) Determination of surface rotational periods for very low-mass stars and brown dwarfs.

(2) Characterization of the properties of surface temperature inhomogeneities and their evolution from analysis of continuous light curves of very cool dwarfs. The inhomogeneities in our targets can be due to two kind of features; cool magnetic spots or cloud decks where dust grains are expected to condense.

(3) Identification of very low-mass eclipsing binaries. So far no eclipsing binaries have been detected with spectral type later than M6.

(4) Characterization of the habitable environment around very low-mass central objects. The habitable regions around late-M and L dwarfs are thought to be tightly wrapped around the central objects. The rate of flare events observed in Halpha emission has been observed to increase toward the late-M spectral types with a peak around M8 and a decrease for later types. However, continuous observations of flare events for timescales of weeks and months in these late spectral type objects are sorely missing.

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420 – AGN, QSO, Blazars III

Oral Session – Room 1, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

420.01D – **X-ray View of Obscured AGN and its Connection with Galaxy Evolution**

Jianjun Jia[1]

[1]The Johns Hopkins University.

2:00 PM - 2:20 PM

Active Galactic Nuclei (AGN) and starburst are two intense and competitive energy releasing phenomena occurring at the centers of active galaxies, and both are often buried by dust and gas. Penetrating the heavy obscuration using X-rays is an efficient tool for probing the galactic centers. To determine the intrinsic obscuration of Type 2 AGNs (where line of sight is intercepted by the obscuring torus) and the fraction of Compton-thick AGN (N_H>10^{24} cm^{-2}), we have studied the archival X-ray data for a sizable sample of Type 2 AGN selected based on their [O III] optical emission lines, which servers as an intrinsic AGN flux proxy. Our results indicate that the majority of the sample are heavily obscured, and the obscuration obtained from the simple spectral fits is under-predicted. Using OIII and Fe Kα emission lines as the intrinsic luminosity indicators and compared with local Seyfert 2s, we find that high AGN luminosities are not strongly impacting the obscuration present in obscured AGN. We also study the X-ray emission from a rare sample of local Lyman Break Analogs (LBAs), which are believed to be AGN/starburst composites based on their optical emission lines. We find X-ray luminosities of order 10^{42} erg/s and ratios of X-ray to far-IR luminosities that are higher than values in pure starburst galaxies by factor of about 10, which strongly suggests the presence of an AGN in at least some of these galaxies. By investigating a starburst merging galaxy which also hosts a Compton-thick AGN, we are also exploring the relative contribution to the X-ray luminosity by both AGN and starburst. Our work provides an X-ray view on obscured AGNs, starburst galaxies and the composite galaxies, which helps to understand the co-evolution of galaxies and black holes.

420.02 – **Composition Of Gas And Dust In Obscured And Unobscured Agn In The Boötes Field**

Shawn Usman[1], S. S. Murray[1], R. C. Hickox[2], M. Brodwin[3]

[1]Johns Hopkins University, [2]Dartmouth College, [3]University of Missouri-Kansas City.

2:20 PM - 2:30 PM

We combine gas absorption and dust extinction parameters of AGN using Chandra X-Ray observations of the NOAO Deep Wide Field Survey of the Boötes Field. AGN at redshifts 0.7 < z < 3 are selected and dust extinction parameters defined on the basis of Spitzer IRAC color-color criterion. We then classify AGN as X-ray unobscured (XRAGN1) or obscured (XRAGN2) based on neutral hydrogen absorption parameters determined from fitting of X-ray spectra. We define obscured AGN as absorbed (N_H > 1.0 x 10^{21} cm^{-2}) by gas local to the source while unobscured AGN have absorption parameters (N_H ~1.5 x 10^{20} cm^{-2}) typical for galactic absorption. X-ray luminosities in the soft (0.2 - 2 keV) and hard (2 - 7 keV) bands in conjunction with hardness ratios are used to further constrain the obscuration classifications. The X-Ray selected AGN are then matched with observations in the IR where obscuration classifications are based on dust extinction. Redshifts for IR unobscured (IRAGN1) AGN are obtained through optical spectroscopy. IR obscured AGN (IRAGN2) lack the optical emission required for spectroscopy, therefore estimated photometric redshifts are used. The X-ray obscuration classifications are compared to their IR counterparts to determine to what extent gas absorption and dust extinction correlate. Such a correlation measure could help constrain the underpinning assumptions behind AGN obscuration models.

420.03 – **Dust-reddened Quasars In First And Ukidss**

Eilat Glikman[1], M. Lacy[2], T. Urrutia[3]

[1]Yale University, [2]NRAO, [3]Leibniz Institut fr Astrophysik, Germany.

2:30 PM - 2:40 PM

We recently identified a large population of dust-reddened quasars by matching radio sources detected in the FIRST survey to the 2MASS near-infrared catalog (F2M) and selecting sources with red topical-to-near-infrared colors. We find that dust-reddened quasars are intrinsically the most luminous quasars in the Universe. Further analysis suggests that red quasars represent an emergent phase in merger-driven quasar/galaxy co-evolution model where the obscured quasar is shedding its dusty shroud prior to becoming a "normal" quasar. Here we use the UKIDSS Large Area Survey (LAS) First Data Release (DR1; 190 deg2) to reach fainter K-band magnitudes and expand beyond the results of the F2M survey. The deeper K-band limit provided by UKIDSS enables the discovery of more heavily reddened quasars at higher redshifts. We selected 95 candidates in the UKIDSS DR1 that had matches in the FIRST catalog with K<17.0 and obeyed color criteria similar to the F2M survey (R-K>5, J-K > 1.5). We have obtained 54 near-infrared spectra as well as ~12 optical spectra from SDSS. Preliminary analysis confirm ~12 new obscured quasars, including at least two with z>2 reaching lower intrinsic luminosities than were found by the F2M survey. We find that despite being a luminous quasar phenomenon, the space density of red quasars continues to rise to fainter magnitudes, representing ~20% of the overall quasar population.

420.04 – **A Wise View Of The Non-thermal Gamma-ray Sky**

Francesco Massaro[1], R. D'Abrusco[2], A. Paggi[2], G. Tosti[3], M. Ajello[4], D. Gasaparrini[5]

[1]Stanford University, [2]Harvard-Smithsonian Center for Astrophysics, [3]University of Perugia, Italy, [4]SLAC/KIPAC, [5]ASDC, Italy.

2:40 PM - 2:50 PM

One of the main scientific objectives of the recent Fermi mission is unveiling the nature of the unidentified gamma-ray sources (UGSs). Despite the large improvements of Fermi in the gamma-ray source localization with respect to the past gamma-ray missions, about 1/3 of the gamma-ray objects detected still do not have a low energy counterpart associated.

Recently, we discovered that blazars, the rarest and the most gamma-ray detected class of Active Galactic Nuclei (AGNs), can be recognized and separated from other extragalactic sources dominated by thermal emission using the IR colors. I will present how the Wide-Field Infrared Survey Explorer (WISE) infrared data make possible to identify a distinct region of the IR color-color diagrams where the sources dominated by the thermal radiation are separated from those dominated by non-thermal emission, in particular the blazar population. This IR non-thermal region of the parameter space, so called WISE Blazar Strip (WBS), it is a powerful new diagnostic tool that can be used to extract new blazar candidates, to identify those of uncertain type and also to search for the blazar-like counterparts of unidentified gamma-ray sources.

First, I will show the relation between the infrared and gamma-ray emission for a selected sample of blazars associated with Fermi sources, for which WISE archival observations are available. Then, for the first time, I will present a possible candidate counterpart for 156 out of 313 UGSs analyzed.

420.05 – **Highlights From Recent Observations Of Gamma-ray Blazars With VERITAS**

Luis C. Reyes[1], VERITAS Collaboration

[1]Cal Polytechnic State University San Luis Obispo.

2:50 PM - 3:00 PM

VERITAS (Very Energetic Radiation Imaging Telescope Array System) is an array of atmospheric Cherenkov telescopes sensitive to gamma rays with energy above 100 GeV. In 4.5 years of operation, VERITAS has detected over 20 blazars with ever increasing multi-wavelength coverage, allowing us to address key questions related to blazar science. This talk will highlight recent results from VERITAS blazar observations, including the scientific prospects for the growing population of intermediate-frequency peaked BL Lac objects with contemporaneous Fermi-LAT

coverage, as well as distant high-frequency peaked BL Lacs.

420.06 – **Synchrotron Emission from Pair Cascades in AGN Environments**

Parisa Roustazadeh[1], M. Boettcher[1]

[1]*Ohio University.*

3:00 PM - 3:10 PM

Recent detections of very-high-energy gamma-ray blazars which do not belong to the high frequency peaked BL Lac class, suggest that gamma-gamma absorption and pair cascade supported by Compton upscattering might occur in those objects. We demonstrate that the magnetic field from the AGN environment can not be determined from a fit of the cascade emission to the gamma-ray spectrum alone, and the degeneracy can only be lifted if the synchrotron emission from the cascades is observed as well. We point out that the cascade synchrotron emission may produce spectral features reminiscent of the big blue bump observed in the spectral energy distributions of several blazars, and illustrate this idea for 3C 279.

421 – Evolution of Galaxies II

Oral Session – Room 3, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

421.01 – **Galaxy Star Formation Histories From Deep Surveys: Why We Still Need A Patchwork Of Star Formation Tracers**

Kai Noeske[1]

[1]*ESA/STScI.*

2:00 PM - 2:10 PM

Scaling laws of galaxy star formation rates (SFR), like the SFR-stellar mass relation ("Galaxy Main Sequence"), allow to derive observational SF histories as a function of, e.g., galaxy mass, environmental density and morphology. They also provide support and new challenges to galaxy models and the understanding of SF physics. Current measurements of the Main Sequence still vary with the choice of SFR tracer and the related calibration and selection effects, and other SF scaling relations will be similarly affected. Rest-frame MIR/FIR data have become a cornerstone of SF history studies and are improving, with Herschel confirming and improving earlier results from Spitzer. However, I show that SFR based on the MIR/FIR alone, while successful for most massive galaxies, are not adequate to measure SFRs in all galaxies, and may even miss certain less massive galaxies with intense SF activity, hence introducing sample selection effects, mainly against objects that are crucial to understand the problem of inefficient SF in sub-L* galaxies at early times. I show how MIR/FIR data can be combined with other SFR tracers to obtain a more comprehensive view of SF and improve on disagreements of previous work.

421.02 – **Spitzer And Herschel-based Seds Of 24um-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]*Caltech,* [3]*Herschel Science Center/Caltech,* [4]*Observatoire de Paris, France,* [5]*University of Western Australia, Australia.*

2:10 PM - 2:20 PM

A key legacy of Spitzer are the mid-IR spectra of high-redshift objects - which would not be available again until the JWST. Such spectra have been very useful for disentangling the contribution of AGN and star-formation to the observed dust emission. We have constructed a unique Spitzer mid-IR spectroscopic, nearly 24um flux-limited sample, of 191 sources at z~0.3-2.8 and with log(L_IR/L_sun)~11-13. The size and selection of the sample, allows us to study galaxy evolution from the perspective of the mid-IR where AGN are prominent. Indeed, mid-IR diagnostics suggest that 70% of our sample is AGN-dominated. Without far-IR data however, it is unclear to what degree this conclusion applies to the overall IR emission. Here we extend the earlier mid-IR studies to incorporate Herschel far-IR photometry and address the full IR SED of Spitzer 24um-selected galaxies. This allows for the overall AGN contribution to their power output to be estimated. This also allows for a direct comparison with other populations both locally and at high redshifts - ultimately placing the 24um-bright populations in the wider context of galaxy evolution. Our first conclusion is that indeed mid-IR studies alone underestimate the level of star-formation in these systems -- we now find that only 19% of the sample are AGN-dominated (i.e. where the AGN luminosity is at least 50% of the total L_IR). We also find that sources of comparable L_IR locally, are not good analogs to the our sources -- consistent for example with recent ideas of cold gas accretion vs. mergers as a means of triggering extreme starbursts. Since local sources are not good analogs to high redshift ones, we construct a set of IR SEDs templates for high redshift starbursts and obscured quasars. The templates are public and useful, among others, for interpreting the all-sky mid-IR data from WISE.

421.03 – **Far-infrared Seds Of Extremely Luminous Infrared Galaxies at z~2 Discovered By Wise**

Lin Yan[1], E. Donoso[1], T. Chao-wei[1], P. Eisenhardt[2], R. Assef[2], D. Stern[2], J. Wu[2]

[1]*Caltech,* [2]*Jet Propulsion Lab.*

2:20 PM - 2:30 PM

Wide field Infrared Survey Explorer (WISE) has completed imaging the entire sky in 4 mid-IR channels from 3.4 to 22microns. One of the early science results from the WISE team is the discovery of a population of extremely luminous infrared galaxies at redshift of 2-3 by using very red WISE colors from 3 to 22 microns. In this talk, I will present the Herschel far-infrared photometric observations in five bands of a subset of these z~2 WISE ULIRGs. Utilizing the well characterized IR SEDs of highly obscured AGNs previous discovered by Spitzer studies, I will shed light on the physical nature of this WISE z~2 sample.

421.04 – **Ultraviolet Observations of the Hubble Ultra Deep Field**

Marc Rafelski[1], H. Teplitz[1], N. Grogin[2], A. Koekemoer[2], B. Siana[3], H. Atek[1], N. A. Bond[4], T. M. Brown[2], D. Coe[2], J. Colbert[1], H. C. Ferguson[2], S. L. Finkelstein[5], J. P. Gardner[4], E. Gawiser[6], M. Giavalisco[7], C. Gronwall[8], D. Hanish[1], P. Kurczynski[6], K. Lee[9], S. Ravindranath[10], C. Scarlata[11], E. Voyer[12], A. Wolfe[13], D. F. de Mello[14]

[1]*IPAC / Caltech,* [2]*Space Telescope Science Institute,* [3]*UC Riverside,* [4]*NASA Goddard Space Flight Center,* [5]*University of Texas at Austin,* [6]*Rutgers the State University of New Jersey,* [7]*University of Massachusetts,* [8]*The Pennsylvania State University,* [9]*Purdue University,* [10]*Inter-University Centre for Astronomy and Astrophysics, India,* [11]*University of Minnesota,* [12]*CNRS, Laboratoire d'Astrophysique de Marseille, France,* [13]*University of California - San Diego,* [14]*Catholic University of America.*

2:30 PM - 2:40 PM

We present details of a 90-orbit HST treasury program to obtain Ultraviolet (UV) imaging of the Hubble Ultra Deep Field (UDF) using the WFC3-UVIS detector with the F225W, F275W, and F336W filters. These UV images will reach point source detection limits of AB=29 at 10 sigma. This survey is designed to: (i) Investigate the episode of peak star formation activity in galaxies at $1 < z < 2.5$. (ii) Study the star formation properties of moderate redshift starburst galaxies. (iii) Probe the evolution of massive galaxies by resolving sub-galactic units (clumps). (iv) Examine the escape fraction of ionizing radiation from galaxies at z~2-3. (v) Measure the star formation rate efficiency of neutral atomic-dominated hydrogen gas at z~1-3. We will present preliminary results from the UVUDF team based on the first observations (beginning March 2012).

421.05 – **The Herschel Lensing Survey (HLS): A Bright Lensed Submillimeter Galaxy in the Field of Abell 773**

Tim Rawle[1], E. Egami[1], M. Rex[1], F. Combes[2], F. Boone[3], I. Smail[4], Herschel Lensing Survey

[1]*University of Arizona,* [2]*Observatoire de Paris, France,* [3]*Universite de Toulouse, France,* [4]*Durham University, United Kingdom.*

2:40 PM - 2:50 PM

The Herschel Lensing Survey (HLS; PI: Egami) is observing more than 50 massive galaxy clusters with deep PACS and SPIRE (100-500um) imaging, and a further ~500 clusters in a SPIRE snapshot program (~20 deg^2 of far-infrared cluster observations in total). Here, we present a discussion of an exceptionally bright (~200mJy at 500um) source behind the cluster Abell 773, which is a strongly lensed submillimeter galaxy (SMG) at z=5.2. The source has an intrinsic infrared luminosity L_FIR ~ 1e13 L_sun, with a total magnification factor of ~11. We combine Herschel-SMA-IRAM observations of the dust continuum and gas excitation line emission, including multiple CO transitions, [CII] and [NII] (detected for the first time at high-z), to explore the morphology, star formation and ISM in this SMG.

422 – Reionization, CMB, and the IGM

Oral Session – Ballroom C, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

422.01 – **The Escape of Ionizing Radiation from Early Galaxies**

Aparna Venkatesan[1], A. Benson[2]

[1]*Univ. of San Francisco,* [2]*Caltech.*

2:00 PM - 2:10 PM

We present calculations of the escape fraction of ionizing radiation from galaxies in the early universe. Such galaxies are the formation sites of the first stars and quasars, which are strong

sources of hard ionizing radiation. The escape fraction is a critical input parameter for any cosmological code or simulation that tracks hydrogen or helium reionization at high redshifts. We present our results on the escape fractions for HI, HeI and HeII across a representative range of galaxy properties including varying source spectral indices, stellar mass functions, metallicities and galaxy density profiles. We also examine these effects on the thermal and ionization history of the intergalactic medium, including the critical

role of X-rays from first-light sources.

422.02 – **He II Quasars: Studying Helium Reionization with a Statistical Sample**

David Syphers[1], S. F. Anderson[2], W. Zheng[3]

[1]*University of Colorado,* [2]*University of Washington,* [3]*Johns Hopkins University.*

2:10 PM - 2:20 PM

The most direct probe of He II reionization is examining Gunn-Peterson troughs in z~3 quasar spectra. Finding "He II quasars" has been challenging, but with new techniques we have raised the success rate from ~5% to 82%. We discuss our new sample of He II quasars (sufficiently large for statistical interpretation), and

prospects for using this sample to understand helium reionization.

422.03 – **The Physics Of The Z~20 21cm Signal**

Matthew McQuinn[1]

[1]*University of California Berkeley.*

2:20 PM - 2:30 PM

Detecting the 21cm line from the pre-reionization era, z~15-25, would reveal information about the formation of the first stellar populations and the thermal history of the Universe. Projects like LEDA and DARE are pursuing this exciting yet difficult venture. I will discuss new analytical and numerical work on the 21cm signal from z~20 that has vast implications for its detectability. I will show that shocks do not heat up the IGM and suppress the 21cm signal as had been speculated. I will also discuss the possibility of the signal being larger than anticipated.

422.04 – **Probing the Inflationary Era with the POLARBEAR Experiment**

Nathan Stebor[1]

[1]*University of California, San Diego.*

2:30 PM - 2:40 PM

Observations of the Cosmic Microwave Background (CMB) have been instrumental in illuminating many of the fundamental properties of the universe and have ushered in widespread acceptance of a Standard Cosmological Model. Current lines of research focus on physics that is beyond this Standard Model, with particular interest given to experimental probes of the inflationary epoch. The inflationary paradigm predicts the existence of a primordial gravitational wave background that imprints a unique 'B-mode' signature onto the polarization of the CMB at large angular scales. This B-mode signal also encodes gravitational lensing information at smaller angular scales, which in turn carries information about large scale structure and may provide information about the properties of cosmological neutrinos. As of this writing, B-mode polarization anisotropy has not yet been measured, though it is expected to be orders of magnitude smaller than the CMB temperature anisotropy signal. This has motivated a new class of experiments that feature unprecedented sensitivity and precise control over systematic effects. The POLARBEAR experiment has been designed specifically to perform a deep search for polarization anisotropy in the CMB and to measure the signature of gravitational waves from inflation on large angular scales and to characterize lensing of the CMB on smaller scales. POLARBEAR is an off-axis 3.5 meter ground-based telescope operating at 150 GHz featuring an array of over 1000 antenna-coupled superconducting transition edge sensor (TES) bolometers cooled to 0.25 Kelvin. POLARBEAR is designed to reach a tensor-to-scalar ratio of 0.025 after two years of observation -- more than an order of magnitude improvement over the current best results, which would test physics at energies near the GUT scale. POLARBEAR achieved first light in January of 2012 and is currently observing in the Atacama Desert in Chile.

422.05 – **An Efficient Algorithm for Separating Cosmic Microwave Background Polarization Maps into E, B, and Ambiguous Components**

Emory F. Bunn[1]

[1]*Univ. of Richmond.*

2:40 PM - 2:50 PM

In analyzing cosmic microwave background (CMB) polarization data, it is very useful to examine the E and B modes separately. For a map covering only part of the sky, the E/B separation is not unique, due to the presence of ambiguous modes. I present an efficient real-space algorithm for removing ambiguous modes and separating the remaining polarization map into "pure" E and B components. The method, which works for arbitrary geometries, involves separating the map into "impure" E and B modes and then purifying each by finding a biharmonic function satisfying appropriate boundary conditions. The rate-limiting step scales as the cube of the number of pixels on the boundary.

422.06 – **The Most Gas-rich Damped Lyman-alpha QSO Absorber Known So far**

Varsha P. Kulkarni[1], J. Meiring[2], D. Som[1], C. Peroux[3], D. York[4], P. Khare[5], J. Lauroesch[6]

[1]*Univ. Of South Carolina,* [2]*Univ. Of Massachusetts, Amherst,* [3]*Laboratoire d'Astrophysique de Marseille, France,* [4]*Univ. Of Chicago,* [5]*IUCAA, India,* [6]*Univ. Of Louisville.*

2:50 PM - 3:00 PM

We report the discovery of a "super-damped" Lyman-alpha absorber at z_abs = 2.2 toward QSO Q1135-0010 in the Sloan Digital Sky Survey, and follow-up VLT UVES spectroscopy. This is the highest-N(HI) QSO DLA discovered to date, with log N(HI) = 22.05 pm 0.10. We present abundances of various elements in this DLA, which imply about 1/10 solar metallicity. Our data indicate detection of Ly-alpha emission in the DLA trough, implying a star formation rate (SFR) of at least 10 solar masses per year in the absence of dust attenuation. We also discuss the detection of C II* and Si II* absorption (the first Si II* detection in an intervening QSO DLA) to estimate the SFR surface density and electron density. Overall, this is a robustly star-forming, moderately enriched absorber, but with relatively low dust depletion. Finally, we compare this absorber with DLAs toward other QSOs and gamma-ray bursts.

This work was funded in part by NSF grants AST-0908890 and AST-1108830.

423 – Corona & Heliosphere

Oral Session – Room 5, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

423.01 – **Observation of Hyperfine Channels of Solar Corona Heating**

Wenda Cao[1], H. Ji[2], P. R. Goode[1]

[1]*Big Bear Solar Observatory,* [2]*Purple Mountain Observatory, China.*

2:00 PM - 2:15 PM

We report here the first direct observations of dynamical events originating in the sun's cool photosphere and subsequently lighting up the corona. Continuous impulsive events have been tracked from their origin in the photosphere on through to their brightening of the local corona. We achieve this by combining high resolution ground-based data from the 1.6 meter aperture New Solar Telescope (NST) at Big Bear Solar Observatory (BBSO),and satellite data from the Atmospheric Imaging Assembly (AIA) on-board the Solar Dynamics Observatory (SDO). The NST observations in a narrow band absorption line, Helium I 10830 Å, reveal unexpected complexes of hyperfine, hot magnetic loops seen to be reaching from the photosphere to the base of the corona. Most of these hyperfine loops are characterized by an apparently constant, but surprisingly narrow diameter of about 100 km all along each loop, and the loops originate on the solar surface from intense, small-scale magnetic field elements. The NST observations detect upward injections of hot plasma that excite the hyperfine loops from the photosphere to the base of the corona. The ejecta have their individual footpoints in the intergranular lanes between the sun's ubiquitous, convectively driven granules. In many cases, AIA/SDO detects co-spatial and co-temporal brightenings in the overlying, million-degree coronal loops in conjunction with the upward injections along the hyperfine loops. Segments of some of the more intense upward injections are seen as rapid blue-shifted events in simultaneous Hα blue wing images observed at BBSO. In sum, the observations unambiguously show impulsive coronal heating events from upward energy flows originating from intergranular lanes on the solar surface accompanied by co-spatial mass flows.

423.02 – **Understanding Coronal Heating with Emission Measure Distributions**

James A. Klimchuk[1], D. Tripathi[2], S. J. Bradshaw[3], H. E. Mason[4]

[1]*NASA GSFC,* [2]*Inter-University Centre for Astronomy and Astrophysics, India,* [3]*Rice University,* [4]*University of Cambridge, United Kingdom.*

2:15 PM - 2:30 PM

It is widely believed that the cross-field spatial scale of coronal heating is small, so that the fundamental plasma structures (loop strands) are spatially unresolved. We therefore must appeal to diagnostic techniques that are not strongly affected by spatial averaging. One valuable observable is the emission measure distribution, EM(T), which indicates how much material is present at each temperature. Using data from the Extreme-ultraviolet Imaging Spectrograph on the Hinode mission, we have determined emission measure distributions in the cores of two active regions. The distributions have power law slopes of approximately 2.4 coolward of the peak. We compare these slopes, as well as the amount of emission measure at very high temperature, with the predictions of a series of models. The models assume impulsive heating (nanoflares) in unresolved strands and take full account of nonequilibrium ionization.

423.03 – **Coordinated Visible, EUV and White Light Observations of the Extended Corona During the 2010 July 11 Total Solar Eclipse**

Shadia R. Habbal[1], E. Landi[2], H. Morgan[3], M. Druckmuller[4], A. Ding[5]

[1]*Univ. of Hawaii at Manoa,* [2]*University of Michigan,* [3]*Aberystwyth University, United Kingdom,* [4]*Brno University of Technology, Czech Republic,* [5]*Institute of Technical Physics, Germany.*

2:30 PM - 2:45 PM

Eclipse observations of coronal forbidden lines emitted by highly ionized elements are unique as they extend the field of view of space-borne high-resolution EUV spectrometers and narrow-band EUV imagers up to several solar radii. Furthermore, they combine in one single dataset the two main features of space-borne instrumentation: high spatial resolution 2D images of the solar corona and full temperature resolution and diagnostic potential allowed by monochromatic imaging of individual spectral lines. The limitation of the published eclipse results, however, has been the absence of an absolute calibration. In the present work, we combine the 2010 July 11 eclipse observations with simultaneous observations carried out with the Hinode/EIS instrument. Such a combination allows us to calibrate the eclipse images and to use them to carry out detailed plasma diagnostics in the extended corona out to a few solar radii using a variety of techniques.

423.04 – **Origin of Rapid Blueshifted Events in Coronal Holes**

Vasyl B. Yurchyshyn[1], K. Ahn[1], V. Abramenko[1], P. Goode[1], W. Cao[1]

[1]*Big Bear Solar Obs..*

2:45 PM - 3:00 PM

Clusters of photospheric bright points are surrounded by chromospheric rosette-like structures. These rosettes, when observed in the far off-band (-0.1nm) Halpha images often appear to consist of short living, narrow rapid blueshifted events (RBEs). RBEs, in turn, are thought to be disk counterparts of type II spicules (spicules II), detected in Hinode data, which may be playing play an important role in coronal heating since they are thought to supply mass to the solar corona. The search for the origin of type II spicules was one of the main focus of solar physics research in the recent years.

Here we present our findings on the possible driving mechanism of spicules II, which are based on high resolution photospheric, chromospheric and magnetic field data from the New Solar Telescope (NST) collected in a coronal hole. We report that the majority of RBEs, occurring around a network cluster, are associated with appearance of opposite polarity features within the unipolar cluster fields, suggesting that magnetic reconnection may be the driving mechanism. We will present these observations in details and discuss possible implications.

423.05 – **The EUV Emission from Sun-Grazing Comets**

Paul Bryans[1], W. D. Pesnell[1]

[1]*NASA Goddard Space Flight Center.*

3:00 PM - 3:15 PM

The Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO) has, to date, viewed two Sun-grazing comets as they passed through the solar corona. Both passages resulted in the significant enhancement of Extreme Ultraviolet (EUV) emission in several of the AIA bandpasses. We explain this EUV emission by considering the evolution of the cometary atmosphere as it interacts with the ambient solar atmosphere. Water ice in the comet rapidly sublimates as it approaches the Sun. This water vapor is then photodissociated by the solar radiation field to create atomic H and O. Other molecules present in the comet also evaporate and dissociate to give atomic Fe and other metals. Subsequent ionization of these atoms produces a high abundance of ions not normally present at the temperature of the corona and results in EUV emission in the wavelength ranges of the AIA telescopes. Understanding the EUV emission places constraints on the cometary composition and provides valuable insight to the nature of the upper solar atmosphere.

423.06 – **Results and Analysis of 10 Years of RHESSI/SAS Observations of the Optical Solar Limb**

Martin Fivian[1], H. S. Hudson[1], R. P. Lin[1]

[1]*Space Sciences Lab/ UC Berkeley.*

3:15 PM - 3:30 PM

The Solar Aspect System (SAS) of the RHESSI satellite measures the optical solar limb in the red continuum with a cadence typically set at 16 samples/s in each of three linear CCD sensors. RHESSI has observed the Sun continuously now for more than 10 years, and we have acquired a unique data set ranging almost over a full solar cycle and consisting of about 25x10^9 single data points. These measurements have led to the most accurate oblateness measurement to date, 8.01+-0.14 milli arcsec (Fivian et al., 2008), a value consistent with models predicting an oblateness from surface rotation. An excess oblateness term can be attributed to magnetic elements possibly located in the enhanced network. New measurements of latitude-dependent brightness variations at the limb lead to a quadrupolar term (a pole-to-equator temperature variation) of 0.04+-0.02 K. We present the analysis of these unique data, an overview of some results and we report on our progress as we apply our developed analysis method to the whole 10 years of data.

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424 – Solar Energetic Events II

Oral Session – Room 4, Dena'ina Center – 6/13/2012 2:00:00 PM to 6/13/2012 3:30:00 PM

424.01 – **Understanding Solar Energetic Events Using the Next Generation Coronagraph: High-resolution Imaging with Diagnostic Capability**

Joseph M. Davila[1]

[1]*Goddard Space Flight Center.*

2:00 PM - 2:15 PM

What is the mechanism for CME initiation? Soon for the first time coronagraphs will image and resolve

the magnetic field structural changes in the Corona that lead to the onset of

Coronal Mass Ejections (CMEs). The data provided by these instruments will for the first time provide a time sequence of high-resolution images showing the looptop regions where reconnection leading to flares and the acceleration of energetic particles takes place. These data will enable the determination of the CME initiation mechanism, without which it is impossible

to understand the physics of the triggering of energetic events on the Sun. The determination of the cause of flare onset would be major step toward

advance forecasting of CME's that drive the radiation environment in near Earth

space, and the solar system in general. These data will also show the magnetic connectivity of the low corona out to the orbit of Solar Probe Plus and Solar Orbiter.

424.02 – **Comparison between Major Confined and Eruptive Flares**

N. Gopalswamy[1], S. Yashiro[1], P. Mäkelä[1], B. R. Dennis[1]

[1]*NASA GSFC.*

2:15 PM - 2:30 PM

Statistical studies have shown that a large fraction of major solar flares (42% M-class and 15% X-class) are not associated with coronal mass ejections (CMEs). The CME-less flares are confined flares as opposed to the eruptive flares associated with CMEs. Confined flares are certainly good particle accelerators as inferred from intense microwave, hard X-ray, and gamma-ray emissions. Note that a single acceleration mechanism operates in confined flares, whereas eruptive flares can have both flare-resident and shock accelerations (the shock acceleration is due to energetic CMEs). In this paper, we report on a statistical study of more than two dozen confined flares with soft X-ray flare size exceeding M5 in comparison with a control sample of eruptive flares with similar soft X-ray flare size. We compare the microwave and X-ray emission characteristics in the two populations; these emissions correspond to sunward energy flow. For a given X-ray flare size, the microwave flux is scattered over a wider range for the eruptive flares when compared to the confined flares. We also compare the metric and longer wavelength radio bursts between the two populations; these emissions correspond to the flow of nonthermal electrons away from the Sun. We find that almost all the confined flares lack metric radio bursts, suggesting that there is very little flow of energy into the interplanetary medium. On the other hand, there is high degree of association between eruptive flares and metric radio bursts. This suggests that in confined flares the accelerated electrons have no access to open magnetic field lines. Finally, we examined the association of EUV waves with the two flare populations. While we find EUV waves in most of the eruptive flares, there was no confined flare with EUV waves. This suggests that CMEs is a necessary condition for the generation of global waves.

424.03 – **Fermi LAT Observation of Highly Energetic Impulsive Solar Flares**

Nicola Omodei[1], F. Longo[2], G. Share[3], M. Briggs[4], D. Gruber[5], Fermi LAT and GBM Collaborations

[1]*Stanford University,* [2]*INFN Trieste, Italy,* [3]*University of Maryland,* [4]*University of Alabama in Huntsville,* [5]*Max-Planck-Institut, Germany.*

2:30 PM - 2:45 PM

The Fermi Large Area Telescope (LAT) is the most sensitive instrument ever deployed in space for observing gamma-ray emission >100 MeV.

This has also been demonstrated by its detection of quiescent gamma-ray emission from pions produced by cosmic-ray protons interacting in the solar atmosphere, and from cosmic-ray electron interactions with solar optical photons.

The Fermi LAT has also detected high-energy gamma-ray emission associated with GOES M-class and X-class X-ray flares, each accompanied by a coronal mass ejection and a solar energetic particle event.

During the impulsive phase, gamma rays with energies up to several hundreds of MeV have been recorded by the LAT. Emission up to GeV energies lasting several hours after the flare has also been recorded by the LAT.

The focus of this presentation will be the results from the observation of the impulsive emission phase in solar flares.

Results from the analysis of the modest GOES M2-class solar flare SOL2010-06-12T00:57 will be reported as well as more-recent detections of impulsive events.

424.04 – **Analysis and Theoretical Interpretation of Fermi-LAT and RHESSI Observations of Solar Flares with Gamma-ray Emission >100 MeV**

Vahe Petrosian[1], Q. Chen[1], N. Giglietto[2], N. Omodei[1], G. Share[3], Y. Tanaka[4], Fermi Collaboration

[1]*Stanford Univ.,* [2]*INFN, Italy,* [3]*Univiversity of Maryland,* [4]*IAS/JAXA, Japan.*

2:45 PM - 3:00 PM

Fermi-LAT has detected >100 MeV emission from several flares, which unlike previous such detection by EGRET on board C-GRO, are not all powerful GOES X-class flares. We will review the observations of these flares by Fermi and RHESSI and other instruments, notably GOES, SDO and ground based observations. As examples of an impulsive and a long duration gamma-ray flare we will focus on the 2010 June 12 and 2011 March 7-8 with 12 hours of gamma-ray emission. Based on the temporal and spectral characteristics of these flares we will discuss the competing processes (i) for production of the gamma-ray and other radiation (leptonic vs hadronic), (ii) affecting the transport of the accelerated particle (turbulence and field geometry), and (iii) those involved in determining the site (CME shock or flaring loop) and mechanism of the acceleration of particles into the GeV range (first or second order Fermi). This paper is presented on behalf of Fermi Collaboration.

424.05 – **Future Gamma-Ray Imaging of Solar Eruptive Events**

Albert Y. Shih[1], R. P. Lin[2], G. J. Hurford[2], N. A. Duncan[2], P. Saint-Hilaire[2], H. M. Bain[2], D. M. Smith[3]

[1]*NASA/GSFC,* [2]*UC Berkeley,* [3]*UC Santa Cruz.*

3:00 PM - 3:15 PM

Solar eruptive events, the combination of large solar flares and coronal mass ejections (CMEs), accelerate ions to tens of Gev and electrons to hundreds of MeV. The energy in accelerated particles can be a significant fraction (up to tens of percent) of the released energy and is roughly equipartitioned between ions and electrons. Observations of the gamma-ray signatures produced by these particles interacting with the ambient solar atmosphere probes the distribution and composition of the accelerated population, as well as the atmospheric parameters and abundances of the atmosphere, ultimately revealing information about the underlying physics. Gamma-ray imaging provided by *RHESSI* showed that the interacting ~20 MeV/nucleon ions are confined to flare magnetic loops rather than precipitating from a large CME-associated shock. Furthermore, *RHESSI* images show a surprising, significant spatial separation between the locations where accelerated ions and electrons are interacting, thus indicating a difference in acceleration or transport processes for the two types of particles. Future gamma-ray imaging observations, with higher sensitivity and greater angular resolution, can investigate more deeply the nature of ion acceleration. The

technologies being proven on the *Gamma-Ray Imager/Polarimeter for Solar flares* (*GRIPS*), a NASA balloon instrument, are possible approaches for future instrumentation. We discuss the *GRIPS* instrument and the future of studying this aspect of solar eruptive events.

424.06 – **Energetic Neutral Atoms (ENAs): A new window on Solar Energetic Particle (SEP) acceleration**

Robert P. Lin[1], L. Wang[1], H. Hudson[1], G. Hurford[1], N. Duncan[1], G. Li[2], A. Y. Shih[3], R. A. Mewaldt[4]

[1]*UC, Berkeley,* [2]*Univ. of Alabama, Huntsville,* [3]*NASA Goddard Space Flight Center,* [4]*Caltech*.

3:15 PM - 3:30 PM

Large solar eruptive events accelerate ions up to GeV energies in both flares and fast coronal mass ejections (CMEs). Measurements of gamma-ray line emission show that up to 10-50% of the total energy released in the flare is contained in the few to 100 MeV ions accelerated in the flare. Observations in the interplanetary medium near 1 AU indicate that the number of SEP (Solar Energetic Particles) ions can be comparable or even up to 1-2 orders of magnitude larger than in flares. These SEPs are believed to be accelerated by shocks driven by fast CMEs at altitudes of from 1.5 to tens of solar radii, with the total energy in the SEPs of order 10% of the total kinetic energy of the CME. The ground-breaking discovery of 1.6-15 MeV energetic neutral atoms (ENAs, produced by charge exchange of SEPs with the ambient corona) from the Sun just prior to an SEP event (Mewaldt et al 2009) suggest the possibility that, for the first time, ions being accelerated by CME shocks close to the Sun can be remotely sensed and imaged, providing a completely new window on SEPs. We present model simulations of the SEP ENA production, and possible techniques for remote sensing and mapping SEP ions from seed particle energies (~5 keV) to 10s of MeV.

R. A. Mewaldt, et al, Astrophys. J., 693: L11-15, 2009.

425 – Under the Radar: The First Woman in Radio Astronomy, Ruby Payne-Scott

Invited Session – Ballroom B, Dena'ina Center – 6/13/2012 3:40:00 PM to 6/13/2012 4:30:00 PM

425.01 – **Under the Radar: The First Woman in Radio Astronomy, Ruby Payne-Scott**

W. Miller Goss[1]

[1]*NRAO.*

3:40 PM - 4:30 PM

Under the Radar, the First Woman in Radio Astronomy, Ruby Payne-Scott

W. Miller Goss, NRAO Socorro NM

Ruby Payne-Scott (1912-1981) was an eminent Australian scientist who made major contributions to the WWII radar effort (CSIR) from 1941 to 1945. In late 1945, she pioneered radio astronomy efforts at Dover Heights in Sydney, Australia at a beautiful cliff top overlooking the Tasman Sea. Again at Dover Heights, Payne-Scott carried out the first interferometry in radio astronomy using an Australian Army radar antenna as a radio telescope at sun-rise, 26 January 1946. She continued these ground breaking activities until 1951.

Ruby Payne-Scott played a major role in discovering and elucidating the properties of Type III bursts from the sun, the most common of the five classes of transient phenomena from the solar corona. These bursts are one of the most intensively studied forms of radio emission in all of astronomy. She is also one of the inventors of aperture synthesis in radio astronomy.

I examine her career at the University of Sydney and her conflicts with the CSIR hierarchy concerning the rights of women in the work place, specifically equal wages and the lack of permanent status for married women. I also explore her membership in the Communist Party of Australia as well as her partially released Australian Scientific Intelligence Organization file.

Payne-Scott's role as a major participant in the flourishing radio astronomy research of the post war era remains a remarkable story. She had a number of strong collaborations with the pioneers of early radio astronomy in Australia: Pawsey, Mills, Christiansen, Bolton and Little. I am currently working on a popular version of the Payne-Scott story; "Making Waves, The Story of Ruby Payne-Scott: Australian Pioneer Radio Astronomer" will be published in 2013 by Springer in the *Astronomers' Universe Series*.

426 – SkyMapper: Surveying the Southern Sky

Invited Session – Ballroom B, Dena'ina Center – 6/13/2012 4:30:00 PM to 6/13/2012 5:20:00 PM

426.01 – **SkyMapper: Surveying the Southern Sky**

Brian P. Schmidt[1]

[1]*RSAA, ANU, Australia*.

4:30 PM - 5:20 PM

SkyMapper is a 1.3m telescope built by the Australian National University as a replacement for the Great Melbourne Telescope lost in the fires that destroyed Mt Stromlo Observatory in 2003. The telescope features an 8sq-degree FOV, which when coupled with a new 16kx16k array, yields 5.7sq-degree sampled at 0.5" per pixel. SkyMapper is undertaking a comprehensive 6-colour, 6-epoch survey of the southern celestial hemisphere - the Southern Sky Survey, as well as a shallow full hemispheric survey to provide photometric and astrometric calibrations to 16mag. Additional time will be used to undertake a limited number of other science programs, including a supernova survey that will help imprive Dark Energy constraints. In addition to reviewing the telescope and its surveys, I will show the first results of the telescope, and discuss how others can work with our team and use the SkyMapper dataset on their own scientific programs.

427 – AAS Members' Meeting

Town Hall – Ballroom C, Dena'ina Center – 6/13/2012 5:30:00 PM to 6/13/2012 6:30:00 PM

You may think you belong to the AAS, but itâ€™s actually the other way around: the Society belongs to you. So please come to the Annual Business Meeting in Anchorage to hear about what is up, nominate members to serve on the the very important Nominating Committee and tell us how we can serve you better. To help encourage attendance, we are providing beer, soft drinks and snacks to all attendees. As you sip some local brew, youâ€™ll hear a report on the Societyâ€™s finances, learn about new initiatives from the AAS Council, and have a chance to raise and comment on issues of concern to you personally and to the astronomical community more generally. Finally, we'll welcome our newly elected leaders to their new positions of service for the coming year. Also, the AAS leadership is especially interested in receiving feedback from members on the current metrics established to guide our efforts in accomplishing our strategic goals and mission (http://aas.org/about/strategic_plan).

428 – Dwarf and Irregular Galaxies

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

428.01 – **Faint and Ultra-Faint Dwarf Galaxies in the M81 Group**

Kristin Chiboucas[1], B. A. Jacobs[2], R. B. Tully[2], L. Rizzi[3], I. D. Karachentsev[4]

[1]*Gemini Observatory,* [2]*IfA, University of Hawaii,* [3]*W.M. Keck Observatory,* [4]*Special Astrophysical Observatory, Russian Federation*.

9:00 AM - 6:30 PM

A CFHT/MegaCam search for faint dwarf galaxies over 65 square degrees in the nearby M81 group turned up 22 new candidates. This survey is complete down to M_r' = -10 within the virial radius of the group. Using HST/ACS and WFPC2 two-color photometry, we have confirmed 14 of these as bona-fide M81 group dwarf galaxy members from tip of the red giant branch distances. These include 3 blue compact dwarfs, a likely tidal dwarf, 1 dwarf irregular, and 9 dwarf spheroidals, one of which, at M_r' ~ -6.8 with effective radius R_e ~ 90 pc , is similar to the ultra-faint dwarf spheroidals being discovered in the Local Group. To a completeness limit of M_r' = -10, we find no evidence for a steep galaxy luminosity function slope; the faint-end slope of -1.3 is inconsistent with theoretical cosmological predictions. With the color-magnitude diagrams we investigate the stellar populations and evolutionary histories of these very faint and small dwarfs in an environment more dynamically active than the Local Group.

428.02 – **Deep LBT+LBC Imaging of Andromeda dSphs**

Rachael Beaton[1], S. R. Majewski[1], R. J. Patterson[1], LBT Science Center

[1]*Univ. of Virginia*.

9:00 AM - 6:30 PM

We present results from a campaign to obtain deep, wide field imaging with the Large Binocular Cameras (LBC) of Andromeda dwarf spheroidal (dSph) galaxies. Since the commissioning of the LBC cameras, we have acquired deep BV photometry for Andromeda 14 (And14), Andromeda 18 (And18) and Andromeda 22 (And22). These particular dSphs were specifically chosen for LBT+LBC deep imaging due to their interesting dynamics within the Andromeda-Triangulum system. More specifically, the projected radial distance and radial velocity of And14 imply that it may not be bound to M31, but this interpretation is highly dependent on a poorly constrained line-of-sight distance. Similarly, the discovery data for And18 suggest that it is at the fringe of the Local Group, while the discovery data for And22 suggest it may be in the M33 halo rather than that of M31. Follow up photometric studies have indicated similar results, but were limited to only 1-2 magnitudes at the top of the red giant branch. Our deeper LBT+LBC imaging places new, crucial constraints on the distances to And14, And18 and And22 that are required to evaluate the true status of these dwarfs. Here we present photometric distances, metallicities and structural parameters from the LBT+LBC photometry for And14, And18 and And22.

428.03 – **Extremely Metal-poor Stars In The Ultra-faint Dwarf Galaxies And Their Relation To The First Galaxies**

Anna Frebel[1]

[1]*Massachusetts Institute of Technology.*

9:00 AM - 6:30 PM

Recent works have shown that the ultra-faint dwarf galaxies (with L<10^5Lsun) contain a relatively large fraction of extremely metal-poor stars and are devoid of solar-type stars. Furthermore, these faint, fully DM dominated galaxies show large [Fe/H] abundances spreads of nearly 3 dex. I will present detailed chemical abundances of ~15 stars with -3.8 < [Fe/H] < -1.4 in six of the ultra-faint dwarf galaxies, including the faintest known galaxy Segue 1. By now, the dwarf galaxies host ~30% of the known metal-poor stars with [Fe/H]<-3.5, making them ideal objects for carrying out stellar archaeology and near-field cosmology. Generally, the abundance signatures of the dwarf galaxy stars closely resemble those of equivalent halo stars, suggesting that the metal-poor tail of the Galactic halo was assembled from early analogs of the ultra-faint dwarfs. Especially the most metal-poor halo stars may all originate from such small, old systems, and future interpretations of the stellar chemical signatures should take this into account.

Furthermore, I will show preliminary evidence for a possible connection between these primitive metal-poor survivor galaxies, and the first galaxies (e.g. atomic cooling halos). Based on hydrodynamical simulations, we have established the nucleosynthetic signatures governing a first galaxy. We compare the predictions with the stellar abundances and conclude that some ultra-faint dwarfs could indeed be surviving first galaxies. The stratgey of closely combining observations with simulation results is already helping to learn more details about the relation between the first galaxies, the surviving dwarfs and their role in building the Milky Way stellar halo.

428.04 – **A Fresh Look at the Detectability of Milky Way Satellites in SDSS**

Maya Barlev[1], B. Willman[1]

[1]*Haverford College.*

9:00 AM - 6:30 PM

The number of known Milky Way dwarf galaxies has doubled over the last 8 years owing to the discoveries made possible by the Sloan Digital Sky Survey (SDSS). These discoveries imply that numerous Milky Way dwarf galaxies remain yet to be seen and also shed new light on the Missing Satellites Problem. Comparing the Milky Way's ultra-faint galaxy population with the predictions of galaxy formation models requires a detailed, quantitative understanding of dwarf detectability. To do this, we simulate hundreds of thousands of dwarf galaxies, insert them into patches of SDSS catalog data, and attempt to recover them using an automated algorithm. This investigation builds upon past work by considering two new effects on dwarf detectability: the variation in data quality across the SDSS survey and dwarf ellipticity. We also simulate the detectability of large scale length (lower surface brightness) dwarfs that were not considered in previous studies. We report the results of our simulations, and compare with the results of previous studies.

428.05 – **The Formation History of the Ultra-Faint Dwarf Galaxies**

Thomas M. Brown[1], J. Tumlinson[1], M. C. Geha[2], R. Munoz[3], E. Kirby[4], J. S. Kalirai[1], D. A. VandenBerg[5], R. Avila[1], J. D. Simon[6], H. C. Ferguson[1], P. GuhaThakurta[7]

[1]*STScI,* [2]*Yale,* [3]*University of Chile, Chile,* [4]*CalTech,* [5]*University of Victoria, Canada,* [6]*Observatories of the Carnegie Institution of Washington,* [7]*UCO/Lick.*

9:00 AM - 6:30 PM

We present initial results from an HST survey of the ultra-faint dwarf galaxies. These Milky Way satellites were recently discovered in the Sloan Digital Sky Survey, and appear to be an extension of the classical dwarf spheroidals to low luminosities, offering a new front in the efforts to understand the missing satellite problem. Because they are the least luminous, most dark matter dominated, and least chemically evolved galaxies known, the ultra-faint dwarfs are the best candidate fossils from the early universe. The primary goal of the survey is to measure the star-formation histories of these galaxies and discern any synchronization due to the reionization of the universe.

428.06 – **Star Formation In *LITTLE THINGS*: A First Look With *Herschel***

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

[1]*New Mexico Tech,* [2]*Lowell Observatory.*

9:00 AM - 6:30 PM

Far infrared atomic and molecular lines from Photodissociation Regions (PDRs) provide us with the means to probe for 'hidden H2', or molecular hydrogen not detected via the usual relation with CO. Having a good grasp on the available H2 reservoir in a galaxy is important for determining its star formation properties. We present a first peek at *Herschel* spectroscopy of five very metal-poor dwarfs in the *LITTLE THINGS* survey. These targets have metallicities of 12+log(O/H) = 7.4 to 7.8. We have maps of [C II] 158 µm, [O I] 63 µm, [N II] 122 µm, and [O III] 88 µm - the major FIR cooling lines - to probe the relation between atomic and molecular gas at low metallicities.

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429 – Lyman Alpha Emitters as Probes of Galaxy Formation and Cosmology

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

429.01 – **Average Metallicity and Star Formation Rate of Lyα Emitters Probed by a Triple Narrowband Survey**

Kimihiko Nakajima[1], M. Ouchi[1], K. Shimasaku[1], Y. Ono[1], J. C. Lee[2], T. Hashimoto[1], S. Foucaud[3], C. Ly[2], D. A. Dale[4], S. Salim[5], R. Finn[6], O. Almaini[7], S. Okamura[1]

[1]*The University of Tokyo, Japan,* [2]*Space Telescope Science Institute,* [3]*National Taiwan Normal University, Taiwan,* [4]*University of Wyoming,* [5]*Indiana University,* [6]*Siena College,* [7]*University of Nottingham, United Kingdom.*

9:00 AM - 6:30 PM

We present the average metallicity and star formation rate (SFR) of Lyα emitters (LAEs) measured from our large-area survey with three narrowband (NB) filters covering the Lyα, [OII]3727, and Hα+[NII] lines of LAEs at z=2.2. We select 919 z=2.2 LAEs from Subaru/Suprime-Cam NB data in conjunction with Magellan/IMACS spectroscopy. By stacking the near-infrared images of 105 LAEs observed with KPNO/NEWFIRM, we obtain average nebular-line fluxes of LAEs, the majority of which are too faint to be identified individually by NB imaging or deep spectroscopy. The stacked object has an Hα luminosity of 1.7x10^{42} erg/s corresponding to an SFR of 14 Msun/yr. We place, for the first time, a firm lower limit to the average metallicity of LAEs of Z>0.09 Zsun (2σ) based on the [OII]/(Hα+[NII]) index together with photoionization models and empirical relations. This lower limit of metallicity rules out the hypothesis that LAEs, so far observed at z~2, are extremely metal-poor (Z<0.02 Zsun) galaxies at the 4σ level. This limit is higher than a simple extrapolation of the observed mass-metallicity relation of z~2 UV-selected galaxies toward lower masses (5x10^8 Msun), but roughly consistent with a recently proposed fundamental mass-metallicity relation when the LAEs' relatively low SFR is taken into account.

In order to test these NIR NB analysis results, we carry out NIR spectroscopy for bright z=2.2 LAEs with Keck/NIRSPEC and Magellan/MMIRS. We successfully detect Hα emission from seven LAEs, two out of which have [OII] and [OIII] line detections. These two LAEs with Hα and multiple oxygen lines provide oxygen abundance estimates of LAEs that complement the previous spectroscopic constraints on metallicity of LAEs from the [NII]/Hα index.

429.02 – **Can Gas Outflows Explain The Strong Lyα Emission Of Lyman Alpha Emitters?**

Takuya Hashimoto[1], M. Ouchi[1], K. Shimasaku[1], K. Nakajima[1], Y. Ono[1], M. Rauch[2]

[1]*The Unversity of Tokyo, Japan,* [2]*Observatories of the Carnegie Institution of Washington.*

9:00 AM - 6:30 PM

Lyman alpha emitters (LAEs) are galaxies commonly seen at high redshift, probably playing an important role in galaxy evolution as building blocks of massive galaxies. The most interesting feature of LAEs is strong Lyα emission, because Lyα photons produced in a galaxy are expected to be easily absorbed by dust in the ISM before escaping the galaxy due to their resonant nature. Previous studies have suggested that outflow may help their escape thanks to reduced cross sections of outflowing (ie, redshifted) neutral hydrogen atoms. Although the presence of outflows can be examined from the offset of the Lyα emission from the systemic velocity defined by Hα emission, there are only four LAEs with reliable detection of Hα emission. We present the results of Magellan/MMIRS and Keck/NIRSPEC spectroscopic observations of five LAEs at z~2.2 from our wide-field narrow-band survey with Subaru/Suprime-Cam. We successfully detect Hα emission for five objects. After eliminating an AGN contaminated object, we measure the velocityoffset between Lyα and Hα (Δ v_Lyα) for the remaining four, to find that three have a positive offset, suggesting an outflow. Since three among the four from the the literature also have an outflow, we conclude that ~75% of LAEs have an outflow, with velocities of 75-280 km/s. We then use these eight LAEs to examine how the Lyα strength defined by Lyα escape fraction (f_esc) and/or Lyα equivalent width (EW(Lyα)) depend on other physical quantities including those derived from SED fitting. Contrary to our expectation, we find that both f_esc and EW(Lyα) decrease with Δ v_Lyα. Thus, although LAEs do have outflow, high outflow velocities are not the primary cause of strong Lyα emission. We also find that the Lyα strength does not depend on E(B-V). However, we find that objects with a clumpier gas distribution may have higher f_esc.

429.03 – **Spectroscopic Confirmation of Three z-Dropout Galaxies at z = 6.844-7.213: Demographics of Lya Emission in z ~ 7 Galaxies**

Yoshiaki Ono[1], M. Ouchi[1], B. Mobasher[2], M. Dickinson[3], K. Penner[4], K. Shimasaku[1], B. J. Weiner[5], J. S. Kartaltepe[3], K. Nakajima[1], H. Nayyeri[2], D. Stern[6], N. Kashikawa[7], H. Spinrad[8]

[1]*University of Tokyo, Japan,* [2]*University of California, Riverside,* [3]*National Optical Astronomical Observatories,* [4]*University of Arizona,* [5]*Steward Observatory, University of Arizona,* [6]*Jet Propulsion Laboratory, California Institute of Technology,* [7]*National Astronomical Observatory of Japan, Japan,* [8]*University of California, Berkeley.*

9:00 AM - 6:30 PM

We present the results of our ultra-deep Keck/DEIMOS spectroscopy of z-dropout galaxies in the Subaru Deep Field and Great Observatories Origins Deep Survey's northern field. For 3 out of 11 objects, we detect an emission line at ~ 1um with a signal-to-noise ratio of ~ 10. The lines show asymmetric profiles with high weighted skewness values, consistent with being Lya, yielding redshifts of z = 7.213, 6.965, and 6.844. Specifically, we confirm the z = 7.213 object in two independent DEIMOS runs with different spectroscopic configurations. The z =

6.965 object is a known Lya emitter, IOK-1, for which our improved spectrum at a higher resolution yields a robust skewness measurement. The three z-dropouts have Lya fluxes of 3 x 10^-17 erg s^-1 cm^-2 and rest-frame equivalent widths EW^Lya 0 = 33-43A. Based on the largest spectroscopic sample of 43 z-dropouts, which is the combination of our and previous data, we find that the fraction of Lya-emitting galaxies (EW^Lya 0 > 25A) is low at z ~ 7; 17% +/- 10% and 24% +/- 12% for bright (Muv ~= -21) and faint (Muv ~= -19.5) galaxies, respectively. The fractions of Lya-emitting galaxies drop from z ~ 6 to 7 and the amplitude of the drop is larger for faint galaxies than for bright galaxies. These two pieces of evidence would indicate that the neutral hydrogen fraction of the intergalactic medium increases from z ~ 6 to 7 and that the reionization proceeds from high- to low-density environments, as suggested by an inside-out reionization model.

429.04 – **Stellar Population Properties of z=4.5 and z=5.7 Lyman Alpha Emitters based on Spitzer Observations**

Keely D. Finkelstein[1], S. L. Finkelstein[1], V. Tilvi[2], S. Malhotra[3], J. E. Rhoads[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 at Austin, [2]Texas A&M University, [3]Arizona State University, [4]Space Telescope Institute, [5]National Optical Astronomy Observatory, [6]University of California at Riverside, [7]University of Science and Technology of China, China.
9:00 AM - 6:30 PM

We present the stellar population modeling for a sample of 168 z=4.5 Lyman Alpha Emitters (LAEs) in the Bootes field, using deep Spitzer/IRAC data at 3.6 and 4.5 microns. We also have a smaller sample of 13 z=5.7 LAEs that were also covered in this Spitzer Lyman Alpha Survey. Of the 168 z=4.5 LAEs, 52 (~30%) were detected in at least one IRAC band, while 10 of the 13 targeted z=5.7 LAEs were detected in at least one IRAC band. We analyze the stellar properties of the individual galaxies that have IRAC detections, as well perform stacking analysis on the IRAC-detected sample and the IRAC-undetected sample. For the z=4.5 LAEs, stacking analysis shows that the average stellar properties of the IRAC-undetected sample are younger and lower mass, with an average stellar mass of ~10^8 solar masses, and an average age of 10 Myr. Whereas stacking analysis on the IRAC-detected sample show they have an average stellar mass of 5x10^9 solar masses, and an average age of 1 Gyr. However when we fit the IRAC-detected galaxies individually we find that the typical masses range from 5x10^8 - 10^11 solar masses, and the ages vary with half of the IRAC-detected LAEs having stellar population ages over 1 Gyr, and the other half with ages between a few Myr - 100 Myr. These results highlight that the z=4.5 LAE population is very heterogenous.

429.05 – **A Search for Diffuse Ly-alpha Emitting Halos around z~2.1 and z~3.1 Ly-alpha Emitting Galaxies**

Alex Hagen[1], J. J. Feldmeier[2], R. Ciardullo[1], C. Gronwall[1], MUSYC Collaboration
[1]Pennsylvania State University, [2]Youngstown State University.
9:00 AM - 6:30 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) 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 (LBGs) Presumably, this Lyman-alpha emission is due to resonant scattering of Ly-alpha within the neutral circum-galactic medium. To further investigate this phenomenon, we have stacked the narrow-band images of the z~2.1 and z~3.1 Ly-alpha emitting galaxies (LAEs) identified in the wide-field narrow-band surveys of Gronwall et al. (2007), Guaita et al. (2010) and Ciardullo et al. (2012). 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 analysis of 233 LAEs at z~3.1 and 208 LAEs at z~2.1 yields no evidence for the existence of diffuse Ly-alpha emission surrounding these low-luminosity objects. The surface brightness profile of the LAEs is very similar to the points spread function of stars in the stacked image. Our surface brightness limits in ergs/s/cm^2/arcsec^2 are 9.9 x 10^-19 (z=2.1), and 8.65 x 10^-19 (z=3.1). These surface brightness limits are low enough that we can rule out the exponential surface brightness profiles suggested by Steidel et al (2011).

We discuss the implications for this null result and speculate on the possible explanations for the differences in extended Ly-alpha emission surrounding LBGs and LAEs including differences in sample selection (such as continuum luminosity) and factors which contribute to the Ly-alpha escape fraction (such as viewing angle).

429.06 – **Cosmic Variance in the Physical Properties of Ly-alpha Emitting Galaxies at 2 < z < 3**

Caryl Gronwall[1], A. Matkovic[2], R. Ciardullo[1], J. J. Feldmeier[3], J. Hay[1], MUSYC Collaboration
[1]Penn State Univ., [2]Swarthmore College, [3]Youngstown State Univ..
9:00 AM - 6:30 PM

We have used the Mosaic camera of the CTIO 4-m telescope to conduct a deep, narrow-band survey of Ly-alpha Emitting Galaxies (LAEs) over the redshift ranges 3.10 < z < 3.13 and 2.04 < z < 2.08 in two 0.3 square degree fields, one centered on the Extended Hubble Deep Field South and the other on SDSS 1030+05. These data, combined with our previous surveys of the Extended Chandra Deep Field South, give us a total survey volume of ~ 400,000 Mpc^3 in z ~ 2.06 and ~ 500,000 Mpc^3 at z ~ 3.1 which has been surveyed down to monochromatic line luminosities of log L ~ 42.3 ergs/s. We analyze the samples of Ly-alpha emitters found in the surveys, and present the LAEs' luminosity, equivalent width, and color distributions, along with some of their physical properties such as internal extinction and star formation rate. Most importantly, we use the information provided by our three survey fields to investigate the effect that cosmic variance has

on these quantities, and on measurements of their evolution.

429.07 – **HETDEX and the Evolution of The Physical Properties of Lyman-Alpha Emitting Galaxies**

Robin Ciardullo[1], C. Gronwall[1], G. Blanc[2], S. Finkelstein[3], E. Gawiser[4], K. Gebhardt[3], HETDEX Collaboration
[1]Penn State Univ., [2]Carnegie Observatories, [3]University of Texas, [4]Rutgers University.
9:00 AM - 6:30 PM

Beginning in Spring 2013, the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) will begin a three year survey of two large regions of sky using VIRUS, an array of blue-sensitive integral-field spectrographs set to cover the wavelength range between 3500 to 5500 Angstroms at R = 800 resolution. These data will cover roughly 300 square degrees in the north (centered near 13 hours, +53 deg) and 140 square degrees along the equator (centered around 1.5 hours), have a filling factor of 1 in 4.5, and detect over 800,000 Lyman-alpha emitting galaxies (LAEs) in the redshift range 1.9 < z < 3.5. While the main goal of HETDEX is to measure the expansion history of the universe via the LAE's power spectrum, these data will also revolutionize our knowledge of the emission-line universe. Using HETDEX, we will be able to explore the 3-D clustering of LAEs, measure their halo masses, and explore their physical properties over a wide range of galactic environments.

In preparation for HETDEX, we have undertaken a 3 year pilot survey of the COSMOS, GOODS-N, MUNICS-S2, and XMM-LSS regions of sky using VIRUS-P, a proto-type integral-field spectrograph placed on the McDonald 2.7-m telescope. This survey covered 169 square arcmin and discovered 104 LAEs with a median line luminosity of log L = 43.03 ergs/s. We will present the physical properties of the LAEs found in the pilot survey, and discuss how their line-luminosities, equivalent widths, star-formation rates, dust content, and Ly-alpha escape fraction change with redshift. We will also discuss the implications of the these observations for the main HETDEX survey.

429.08 – **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.
9:00 AM - 6:30 PM

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. 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 using the ratio of fluxes between the two filters to identify the precise wavelength where the emission line falls. 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 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.

429.09 – **The Reddening Curve below 1200 Angstroms.**

Aida Wofford[1], C. Leitherer[1]
[1]STScI.
9:00 AM - 6:30 PM

Thirty percent of the bolometric luminosity of star-forming galaxies is emitted in the wavelength range between 912 and 1200 Å. This wavelength range carries information about the stellar mass distribution and the star formation rate of the newly formed populations of massive (M > 8 M_sun) stars in these galaxies, and about the leakage of Lyman-continuum photons from these galaxies. This is also the wavelength range where the reddening curve peaks, and where our understanding of the reddening curve is the most fragmentary. We present preliminary results from a spectroscopic study aimed to characterize the reddening curve below 1200 Å. Our project is based on the analysis of archival HUT (830-1850 Å), FUSE (905-1187 Å), IUE (1150-3200 Å), and HST (1200-3200 Å) data of a sample of ~70 low-redshift (z<0.1) star-forming galaxies, using synthetic spectra of stellar populations plus the ISM. The stellar population and nebula models were generated with STARBURST99 and CLOUDY, respectively. This work is supported by NASA J1401.

430 – Relativistic Astrophysics, Black Holes, Neutron Stars, White Dwarfs, Gravitational

Waves

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

430.01 – **Synthetic Spectral Analysis of the Far Ultraviolet Spectra of the Old Nova HR Del**

Jordan Robertson[1], E. Sion[1]

[1]*Villanova University.*

9:00 AM - 6:30 PM

We present a synthetic spectral analysis of the archival IUE far ultraviolet spectra of the post-nova, HR Del (Nova Del 1967). The system has an estimated white dwarf mass of 0.55 Msun (Ritter and Kolb 2003), orbital period P_orb = 0.214165 days, estimated orbital inclination of ~ 40 degrees (Keurster 1988) and distance determinations in the literature ranging from 970 pc to 285 pc. The spectra reveal P Cygni profiles indicative of wind outflow from the disk and closely resemble the IUE spectra of UX UMa nova-likes, which have never had recorded outbursts. We de-reddened the archival IUE spectra using E(B-V) = 0.16. Our synthetic spectral analysis utilized optically thick, steady state accretion disk models and white dwarf model atmospheres that we constructed using TLUSTY and SYNSPEC (Hubeny 1988, Hubeny and Lanz (1995). Our input parameters were the white dwarf mass, inclination and a range of accretion rates for which we found the best-fitting model. We report the results of our model fitting and compare HR Del with other post-novae at comparable times past their nova outburst.

This work was supported by NSF grant 0807892 to Villanova University

430.02 – **The Distribution of Spectroscopic Subtypes and Kinematics of White Dwarfs within 25 pc of the Sun**

Janine Myszka[1], E. M. Sion[1], J. B. Holberg[2], T. D. Oswalt[3], G. P. McCook[1], R. Wasatonic[1]

[1]*Villanova University,* [2]*University of Arizona,* [3]*Florida Institute of Technology.*

9:00 AM - 6:30 PM

We present the distribution of spectral types and space motions for all of the known white dwarfs within 25 pc of the Sun. The total sample of 205 degenerates with accurate distances, temperatures and confirmed spectral types, consists of 120 DA stars ranging in temperature from 4590K to 25193K, 2 DB stars, 1 DBQZ star, 24 DC stars, 17 DQ stars, 12 DAZ stars, 10 DZ stars, 12 magnetic DA stars, 5 magnetic non-DA stars, and 3 DQZ and DZA stars. The magnetic white dwarfs account for 8% of the sample. The overall DA/non-DA ratio of the 25 pc sample is 2.4:1, while the ratio of magnetic DA to magnetic non-DA is also 2.4:1. We present histograms of the distribution functions of spectroscopic subtype versus surface temperature and of the vector components of the space motions for each spectral subtype.

This work is supported by NSF grant 1008845.

430.03 – **A Marvelous Star in M33**

Elisha Polomski[1], R. D. Gehrz[2], K. McQuinn[2], F. Paffel[1], C. E. Woodward[2]

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9:00 AM - 6:30 PM

The end stages of stellar evolution release heavy element enriched dust into the interstellar medium where it is eventually incorporated into star formation regions and later generations of stars. As low mass stars go through this process they bloat in size, pulsate, and expel dust and gas before ultimately transforming into planetary nebulae (PNe). A classic example of this stage of evolution is the well studied class of pulsating stars, the Mira variables. Prior to expelling a PNe, these objects go through a short (tens of thousands of years) stage of evolution where they undergo episodic mass loss and become enshrouded in dust. We report the discovery of an unusual Mira star within the M33 galaxy; IRAC 0134+3029. The source is heavily obscured in the visible, indicating large amounts of enshrouding dust. In addition, Spitzer Space Telescope spectroscopy and imaging show strong thermal emission as well as absorption features from silicates. Examination of the properties of IRAC 0134 suggests that it is the extragalactic analog of the well known "extreme" Mira OH26.5+0.6. We compare spectra and photometry of IRAC 0134 to observations of OH26.5+.6 as well as to the prototype of the Mira class, Omicron Ceti. We also discuss some contradictory archival observations of these objects and suggest possible explanations.

This work is based upon observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under NASA contract 1407. The authors were supported in part through contracts 1256406 and 1215746 issued by JPL/Caltech to the University of Minnesota.

430.04 – **Status Report On The Wise Infrared Excesses around Degenerates (WIRED) Survey**

D. W. Hoard[1], J. H. Debes[2], S. Wachter[1], D. T. Leisawitz[3], M. Cohen[4]

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9:00 AM - 6:30 PM

The Wide-field Infrared Survey Explorer (WISE) is a NASA medium class Explorer mission that was launched on 14 Dec 2009. WISE mapped the entire sky at 3.4, 4.6, 12, and 22 microns with 5-sigma point source sensitivities of approximately 0.08, 0.11, 1, and 6 mJy, respectively. Complete sky coverage was achieved in mid-July 2010. We have been carrying out the WISE InfraRed Excesses around Degenerates (WIRED) Survey, with the goals of characterizing white dwarf (WD) stars in the WISE bands, confirming objects known to have IR excess from past observations (Spitzer, 2MASS, UKIDSS, etc.), and revealing new examples of WDs with IR excess that can be attributed to unresolved companions or debris disks. We are utilizing target lists drawn from cataloged WD samples (e.g., from the Sloan Digital Sky Survey, McCook & Sion, etc.). To date, we have published results from WIRED for the SDSS WD sample that have nearly tripled the number of known dusty WDs and increased the number of WD + brown dwarf binaries by almost an order of magnitude. We present an update on the status, results, and future plans for the WIRED Survey, concentrating on new discoveries from the McCook & Sion Catalog of Spectroscopically Identified WDs. This work was supported in part by the NASA Postdoctoral Program (J.H.D.), and is based on data from: WISE, a joint project of UCLA and JPL/Caltech, funded by NASA; the UKIRT Infrared Deep Sky Survey; the Two Micron All Sky Survey, a joint project of the University of Massachusetts and IPAC/Caltech, funded by NASA and the NSF; and the Sloan Digital Sky Survey.

430.05 – **Magnetic Fields And Self-gravity In Gravitational Wave Emission From Magnetars**

Shane L. Larson[1], P. Purdue[2]

[1]*Utah State University,* [2]*Colorado College.*

9:00 AM - 6:30 PM

Recent considerations of the gravitational wave emission from magnetars have focused on the contribution from the rotating electromagnetic field, but neglected the contribution from the star's self-gravity. This work reconsiders the problem using a curved space treatment of the electromagnetic field in the slowly rotating limit, and includes contributions from the star's self-gravity, the electromagnetic field and the fluid body.

430.06 – **Dispersion Measure Variations In The Direction Of The High Galactic Latitude Pulsars PSR B1257+12 And PSR B1534+12**

Brett Scheiner[1], A. Wolszczan[1]

[1]*Pennsylvania State University.*

9:00 AM - 6:30 PM

We report the long term dispersion measure (DM) variations of the high galactic latitude pulsars PSR B1257+12 and PSR B1534+12. The slopes of the DM structure functions between scales of 10^{10} to 10^{14} meters were used to determine the power law index of the electron density fluctuation spectrum. The determined power law indicies were 3.90 ± .04 for PSR B1257+12 and 3.67 ± .03 for PSR B1534+12. The value of the power law index for PSR B1534+12 was consistent with a Kolmogorov turbulent electron density fluctuations characterized by refractive and diffractive scintillations. The power law index of PSR B1257+12 is slightly less than the critical value of 4 corresponding to non turbulent electron density fluctuations. This suggests an enhancement of large scale turbulence in the direction of this pulsar. The diffractive timescales at 430 MHz were also determined from the structure function to be 244±42 seconds for PSR B1257 and 269±51 seconds for PSR B1534 which are consistent with the values measured from the dynamic spectra of interstellar scintillation.

430.07 – **Regular and Chaotic Motion in General Relativity. Case of Magnetized Black Hole and a Massive Magnetic Dipole**

Vladimir Karas[1], J. Kovar[2], O. Kopacek[1], Y. Kojima[3], P. Slany[2], Z. Stuchlik[2]

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9:00 AM - 6:30 PM

Near a rotating black hole, circular motion of particles, dust grains and complex fluids have been investigated as a model for accretion of gaseous and dusty environment in the toroidal geometry. Here we further discuss, within the framework of general relativity, figures of equilibrium of matter under the influence of combined gravitational and large-scale magnetic fields, assuming that the accreted material acquires a small (but non-vanishing) electric charge due to the interplay of plasma processes and photoionization. We employ different solutions for the central body (magnetized Kerr metric, or a massive magnetic dipole) and we identify the corresponding regions of stability.

The action of gravitational and electromagnetic forces jointly determine the regions of stable motion, in particular, whether the halo lobes develop where particles can be captured in permanent circulation around the central body. Therefore, our set-up is relevant in the context of accreting compact objects where the halo motion can describe the overall global motion through corona of an accretion disc or a geometrically thick torus. We also investigate situations when the motion exhibits the onset of chaos. In order to characterize the measure of chaoticness we employ techniques of Poincare surfaces of section and Recurrence plots.

Acknowledgments: Czech-US collaboration project (ref. ME09036) and the Czech Science Foundation program (ref. P209/10/P190) are gratefully acknowledged for their continued support.

430.08 – **The Local Black Hole - Mass Function Derived from Spiral Galaxies**

Benjamin L. Davis[1], J. C. Berrier[1], L. Johns[2], D. W. Shields[1], D. Kennefick[1], J. Kennefick[1], M. S. Seigar[3], C. H. S. Lacy[1]

[1]*University of Arkansas,* [2]*Reed College,* [3]*University of Arkansas at Little Rock.*

9:00 AM - 6:30 PM

Here we present our determination of the black hole - mass function for spiral galaxies in our local universe. We have established our black hole - mass function from a volume-limited sample, consisting of a statistically complete collection of

the brightest spiral galaxies in the Southern ($\delta < 0°$) hemisphere. The volume-limited sample is defined by a limiting redshift of z = 0.0068 and a limiting absolute B-band magnitude of M_B = -19.528. These limits define a sample of 140 spiral galaxies. We have measured pitch angles for 102 of these (the remainder did not allow for accurate measurement) and established the pitch angle distribution function for this volume-limited sample. We then used our established relationship between the logarithmic spiral arm pitch angle and the mass of the central supermassive black hole in a host galaxy in order to indirectly estimate the mass of the 102 respective supermassive black holes in this volume-limited sample. This result effectively gives us the distribution of mass for supermassive black holes residing in spiral galaxies over the past ≈94.5 Myr of the history of the universe and contained within a comoving volume of ≈50,000 cubic Mpc. The authors gratefully acknowledge support for this work from NASA Grant NNX08AW03A.

430.09 – **Busting Up Binaries: Stellar Interactions With Galactic Supermassive Black Holes**

Eric Addison[1], S. Larson[1], P. Laguna[2]

[1]*Utah State University,* [2]*Georgia Institute of Technology.*

9:00 AM - 6:30 PM

Gravitational wave astronomy is a new observational tool that will enhance our understanding of the Cosmos. Virtually everything we know about the Cosmos has been learned through observations of light; gravitational waves are a fundamentally different spectrum that can be used to learn about distant astrophysical systems. Einstein's theory of General Relativity predicts the existence of gravitational waves, and it is well known that stellar-mass compact object (CO) binaries will be among the most abundant and easily detectable sources. Extreme mass ratio inspirals are expected to provide an interesting potential source for gravitational wave detectors, however these systems are generally studied in the context of a single star orbiting a black hole. In this work, the case of a CO binary on a parabolic trajectory around a super massive black hole (SMBH) is considered. Numerical simulations are used to explore perturbations to the orbital parameters of the binary after interaction with the SMBH, including de-circularization and possible tidal capture. Additionally, the binary will likely experience an accelerated merger time due to gravitational radiation, which could produce an increase in the predicted CO binary merger rate.

430.1 – **Pitch Angles Of Artificially Redshifted Galaxies**

Douglas W. Shields[1], B. Davis[1], L. Johns[2], J. C. Berrier[1], D. Kennefick[1], J. Kennefick[1], M. Seigar[3]

[1]*University of Arkansas,* [2]*Reed College,* [3]*University of Arkansas Little Rock.*

9:00 AM - 6:30 PM

We present the pitch angles of several galaxies that have been artificially redshifted using Barden et al's FERENGI software. The (central black hole mass)-(spiral arm pitch angle) relation has been used on a statistically complete sample of local galaxies to determine the black hole mass function of local spiral galaxies. We now measure the pitch angles at increasing redshifts by operating on the images pixel-by-pixel. The results will be compared to the pitch angle function as measured in the GOODS field. This research was funded in part by NASA / EPScOR.

430.11 – **Gravitational-Wave Extraction by the Characteristic Method**

Maria Babiuc-Hamilton[1]

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9:00 AM - 6:30 PM

Gravitational interactions govern the entire universe. When a pair of black holes spiral into each other and collide, the very fabric of space-time shakes, and gravitational waves are created. As with any other type of radiation, gravitational waves carry information about their source, and it is anticipated that they will play a key role in our understanding of relativistic systems in astrophysics.

Gravitational wave observatories like LIGO and Virgo are tuned to detect the emission of these waves from the inspiral and merger of binary black holes. The problem is that the observatories detect any small vibration, so templates are essential to tell the real signal from the noise. The correct modeling of gravitational radiation is a key requirement for the meaningful detection and scientific interpretation of the data. However, it is not easy to compute the waveforms obtained from numerical simulations accurately.

Gravitational radiation is properly defined only at future null infinity, but mathematically it is estimated at a finite radius. Cauchy-Characteristic Extraction (CCE) is the most precise and refined "extraction" method available. The CCE technique connects the strong-field "Cauchy" evolution of the space-time near the merger to the "characteristic" evolution far from the merger_at future null infinity, where the waveform is extracted and detectors will measure it.

We present a stand-alone "characteristic" waveform extraction tool that has demonstrated accuracy and convergence of the numerical error and is used by the numerical relativity community for the unambiguous, accurate and efficient extraction of gravitational waveforms. We prove that the numerical error introduced by CCE satisfies the standards of the detection criteria required for Advanced LIGO data analysis. The tool provides a means for accurate calculation of waveforms generated by evolution codes based upon different analytic formulations and numerical approximations of the Einstein equations.

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431 – Planetary Nebulae, Supernova Remnants

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

431.01 – **A Dust Twin of Cas A: 21-micron Dust Feature and Cold Dust in the Supernova Remnant G54.1+0.3**

Jeonghee Rho[1], S. Park[2], A. Boogert[3], H. Gomez[4], W. Reach[5], D. Dowell[5], P. Lagage[6]

[1]*SETI Institute and SOFIA Science Center/NARC,* [2]*NASA Ames Research Center,* [3]*NHSC/Caltech,* [4]*Cardiff U.,* [5]*SOFIA Science Center/USRA,* [6]*Saclay, France.*

9:00 AM - 6:30 PM

We present Spitzer and submm observations of a Crab-like supernova remnant, G54.1+0.3. We serendipitously discovered a dust feature peaking at 21 micron from G54.1+0.3, and the 21-micron dust is remarkably similar to that of Cas A from Rho et al. (2008). The IRS spectrum from the western shell shows the 21-micron dust feature and strong [Ar II] and weak [Ne II], [S III] and [Si II] lines. Strong correlation between 21-micron dust and Ar ejecta has been observed in Cas A. The dust coincides with the ejecta emission, suggesting that dust has been formed in ejecta. We also present detection of cold dust from G54.1+0.3 using SHARCII (at 350 micron) and LABOCA (at 870 micron). Archival Herschel images confirmed the presence of cold dust. We present spectral fitting of SED using continuous distributions of ellipsoidal (CDE) grain models and find that silica (SiO2) is mainly responsible for the 21-micron feature. We will discuss dust properties and inferred dust mass from G54.1+0.3 using the SED from 5 to 870 micron including Herschel data and implication of supernova-dust production in the early Universe.

431.02 – **An Archival X-ray 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[1]

[1]*Harvard-Smithsonian, CfA.*

9:00 AM - 6:30 PM

We present the results of an analysis of the archival XMM-Newton EPIC data (totaling more than 500ks) and Chandra X-ray Observatory ACIS data (89ks) 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 and Chandra 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.

431.03 – **The Chandra Planetary Nebula Survey (ChanPlaNS): Diffuse X-ray Emission from Hot Bubbles**

Kevin Christiansen[1], J. Kastner[1], R. Montez[1], ChanPlaNS Team

[1]*Rochester Institute of Technology.*

9:00 AM - 6:30 PM

Previous studies of nearby planetary nebula (PNe) have revealed that several exhibit diffuse X-ray emission associated with wind-shock-generated "hot bubbles." We are presently undertaking a Chandra X-ray imaging survey of all PNe within 1.5 kpc. In the first phase of this survey, ChanPlaNS has observed 10 PNe that display "hot bubble" X-ray emission. We present detailed results for the 4 best detected cases of such emission (NGC 2392, 3242, 6826, and 7009.) Three of these PNe harbor X-ray-luminous point sources at their central stars (CSPNe), while soft, diffuse X-ray emission tracing shocks, most likely formed by energetic wind collisions is detected in all 4. We present the results of modeling the isolated point source and diffuse emission in order to characterize the shocks and mechanisms underlying the CSPNe point source X-ray emission.

431.04 – **High-Energy Emission From the Composite Supernova Remnant MSH 15-56**

Tea Temim[1], P. Slane[2], P. Plucinsky[2], J. Gelfand[3], D. Castro[4]

[1]*NASA GSFC/ORAU,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*New York University Abu Dhabi, United Arab Emirates,* [4]*MIT Kavli Institute.*

9:00 AM - 6:30 PM

Composite supernova remnants (SNRs) are those consisting of a central pulsar that produces a wind of synchrotron-emitting relativistic particles, and a supernova (SN) blast wave that expands into the surrounding interstellar medium (ISM). At the late stages of a composite SNR's evolution, the SN reverse shock crushes the pulsar wind nebula (PWN), resulting in complex filamentary structures and mixing of the PWN material with ejecta gas. This interaction is even more complex in cases where the PWN is displaced from the SNR center, either due to the pulsar's motion or an asymmetric reverse shock resulting from a density gradient in the ambient ISM. The composite nature of the SNR MSH 15-56 is clearly seen in the radio observations that show an SNR shell with a displaced PWN. We present an

updated analysis of the XMM-Newton and Chandra X-ray observations of this remnant that reveals complex structures indicative of a disrupted PWN and provides evidence for mixing of the SN ejecta with PWN material following a reverse shock interaction. The increase in the magnetic field due to such an interaction produces an excess of low energy particles and may give rise to gamma-ray emission through inverse Compton scattering. Indeed, a gamma-ray source recently detected by Fermi appears to spatially coincide with the SNR, and may originate from the PWN. We discuss the SNR parameters derived from the X-ray observations and the possible origin of the high-energy gamma-ray emission.

431.05 – **Are Pulsar Velocities Correlated with Supernova Remnant Ejecta Asymmetries?**

Laura A. Lopez[1], E. Ramirez-Ruiz[2]

[1]MIT, [2]University of California Santa Cruz.

9:00 AM - 6:30 PM

Proper motion studies have demonstrated that pulsars move with velocities much greater than those of their massive progenitors. These velocities span a distribution, with a mean of ~380 km/s, and some pulsars are observed to have speeds up to two thousand km/s. These high speeds may arise from "kicks" imparted by asymmetric supernova explosions. To explore this scenario, we investigate whether ejecta asymmetries in supernova remnants (SNRs) are correlated with the inferred velocities of their central pulsars/neutron stars. In particular, we measure the asymmetry of ten SNRs in archival X-ray images using a multipole expansion technique, and we compare the results to pulsar/neutron star velocities from the literature. We find evidence that the SNRs with the fastest moving pulsars have the most mirror asymmetric ejecta, suggesting that pulsar kicks are indeed the result of asymmetry in the explosion mechanism.

431.06 – **SN 1957D in M83: A Young Supernova Remnant Emerges**

P. Frank Winkler[1], K. S. Long[2], W. P. Blair[3], R. Soria[4], L. E. H. Godfrey[4], K. D. Kuntz[3], P. P. Plucinsky[5], B. C. Whitmore[2]

[1]Middlebury College, [2]STScI, [3]Johns Hopkins University, [4]Curtin University, Australia, [5]Smithsonian Astrophysical Observatory.

9:00 AM - 6:30 PM

We report recent multi-wavelength observations of the remnant from SN 1957D, a core-collapse supernova in M83 and one of six SNe M83 has produced in the past century. SN 1957D was recovered as a radio SNR by Cowan & Branch (1983), and optically by Long et al. (1988). We have recently detected it for the first time in X-rays, in a long observation from Chandra. New HST WFC3 images resolve the SNR from the complex surrounding emission and reveal the local star field. The optical flux from SN 1957D is dominated by broad [O III] emission lines, the signature of fast-moving SN ejecta. The [O III] flux dropped precipitously between 1989 and 1991; a series of subsequent observations indicates continuing but more gradual decline. The width of the broad lines has remained roughly constant at about 3000 km/s (FWHM). At radio wavelengths, observations over the period 1990-2011 show a decline rate Sν ~ t-3.9, far steeper than the rate observed between 1984 and 1990. Such evolution suggests early expansion into a circumstellar medium dominated by wind material from the progenitor, followed by a steeper decline as the blast wave overruns the edge of the wind material. The X-ray luminosity (0.3 - 10 keV) is 2.0 E37 erg/s, with a relatively hard spectrum. We cannot distinguish between a power law (indicating a probable pulsar and surrounding nebula) vs a hot thermal spectrum from the blast wave. However, the absorption is relatively high, NH ~ 2 E22 cm-2, suggesting a dense local environment. Photometry of the local stellar population around SN 1957D, using HST WFC3 images, indicates a log(age) ~ 7.3 and (remaining) stars up to about 11 M. This research is supported primarily by NASA through Chandra Grant G01-12115; PFW acknowledges additional support from NSF Grant AST-0908566.

431.07 – **Detailed X-Ray Study of O-Rich Supernova Remnant 0049-73.6 in the Small Magellanic Cloud**

Andrew Schenck[1], K. J. Borkowski[2], D. Burrows[3], J. P. Hughes[4], J. Lee[5], K. Mori[6], S. Park[1], S. P. Reynolds[7], P. Slane[8]

[1]University of Texas at Arlington, [2]NC State University, [3]Penn State Univ., [4]Rutgers University, [5]Korea Astronomy and Space Science Institute, Korea, Republic of, [6]Univ of Miyazaki, Japan, [7]North Carolina State University, [8]Harvard-Smithsonian, CfA.

9:00 AM - 6:30 PM

Based on our deep 450 ks Chandra observation, we present our preliminary analysis of the oxygen-rich supernova remnant (SNR) 0049-73.6 in the Small Magellanic Cloud (SMC). We performed image and spectral analyses of the central ejecta nebula and the outer blast wave shock. Our line equivalent width maps of several elements (e.g., O, Ne, Mg, and Si) show a differential spatial structure of ejecta enriched in these species. Our detailed spatially-resolved spectral analysis of the central ejecta features show radial and azimuthal structures of ejecta elements and their thermal states. We also investigate the true 3-D nature of the central ejecta ("ring" vs spherical shell) by studying the surface brightness profile and applying an image de-projection method.

431.08 – **The Rapid Growth of the Fingertips of Preplanetary Nebula CRL618**

Bruce Balick[1], A. Frank[2], M. Huarte-Espinosa[2], T. Gomez[3], R. Corradi[4], J. Alcolea[5]

[1]Univ. of Washington, [2]Univ. of Rochester, [3]Univ. of Texas at Austin, [4]Instituto de Astrofísica de Canarias, Spain, [5]Observatorio Astronomico Nacional, Spain.

9:00 AM - 6:30 PM

HST images taken over a time span of 11 years show that the tips of its bright optical fingers have proper motions exceeding 1". At the presumed distance of 0.9 kpc, the proper motions are equivalent to projected speeds of over 400 km s^-1. However, optical STIS spectra (Riera et al 2011) and our narrow-band images from the tips of the fingers suggest that the radiation arises at a shock speed Vs ~ 80 km s^-1. A forward shock at Vs >150 km s^-1 is far too fast to be observable except, perhaps, in x-rays. So the observed emission lines must arise from a secondary shock driven into the clump or jet (the latter case seems highly unlikely). We will present highlights of hydro models that compare the expected differences of excitation and the shock structures between clumps and jets.

431.09 – **Compact Disks Inside Pre-Planetary Nebulae**

Stacey N. Bright[1], O. De Marco[1], O. Chesneau[2], E. Lagadec[3], H. van Winckel[4], B. Hrivnak[5]

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9:00 AM - 6:30 PM

Disks are known to exist around evolved, mass-losing Asymptotic giant branch (AGB) and post-AGB stars and are suspected to play a fundamental role in the shapes of planetary nebulae (PNe). 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 we have observed 8 pre-PNe, with several showing evidence of disks in their inner-circumstellar regions. We are using MC3D to conduct detailed radiative transfer models of these disks. We are deriving parameters such as inner and outer radii, scale-height, mass, and inclination.

431.1 – **Using Hubble Space Telescope Images to Test Theoretical Models of Planetary Nebulae**

Kelsey M. Braxton[1], B. Balick[1], R. Jacob[2], M. Steffen[2], D. Schonberner[2]

[1]University of Washington, [2]Leibniz Institute for Astrophysics Potsdam, Germany.

9:00 AM - 6:30 PM

Classical ionization models that predict the ionization structure of planetary nebulae generally assume constant gas density (or a central void and constant density) in the shell. More recently, Steffen, Jacob, Schoenberner (2005, A&A, 441, 573) have computed fully consistent one-dimensional radiation hydrodynamic ionization models (RHI models) with realistic stellar winds and evolving central stars. Their numerical results offer concrete predictions concerning the projected three-dimensional shapes of simple round and elliptical PNe. A first glance at their models shows them to be a superior way of modeling ionization structures in realistic PNe. We present high-spatial resolution and carefully flux calibrated images of PNe selected in Halpha, [OIII], and [NII] as well as the ratios [OIII]/Halpha and [NII]/Halpha in order to test the predictions of the RHI models. These were obtained uniformly and at the same epoch using the WFPC2 camera on the Hubble Space Telescope. Some of the targets are ionization bounded and others are density bounded. In the future these images will be compared to the models in detail. At this point we note many of the common features--some of them unexpected--that the models must explain.

431.11 – **X-ray Observations of Vela Supernova Remnant Ejecta Fragments**

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9:00 AM - 6:30 PM

As one of the nearest SNRs, the Vela Supernova Remnant (SNR) subtends more than 8 degrees on the sky, making it ideal for spatially resolved spectral studies. Its environment is complex, and the remnant shows marked variations: the remnant is bright, soft, and sharply defined to the east and north, but much fainter and less well ordered in the west and south. Age estimates for the associated pulsar range from $sim11400$ years to as much as 18000 years, making the the SNR a moderately old remnant. The remnant shows curious protrusions beyond the projected rim (Aschenbach et al. 1995, Nature 373, 587). Many have subsequently been investigated in X-rays and in each case, enhanced abundances have been detected, confirming that these fragments include ejecta. Here, we present analyses of several ejecta fragments based on Suzaku and XMM-Newton X-ray observations.

This work was supported by NASA grants NNX06AE40G, NNX07AF67G, NNX08AZ74G, and by NASA contract NAS8-03060.

431.12 – **The Nature of the H2 Emitting Gas in the Crab Nebula**

Chris T. Richardson[1], J. A. Baldwin[1], G. J. Ferland[2], E. D. Loh[1], C. A. Kuehn[1], C. R. O'Dell[3], A. C. Fabian[4], P. Salome[5]

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9:00 AM - 6:30 PM

We use a combination of NASA ADP data and new ground-based observations to

study the molecular cores located in the Crab nebula's filaments. Knot 51 is a spatially isolated knot of H2 for which we present long slit optical and NIR spectra covering emission lines from ionized, neutral, and molecular gas, as well as, HST and ground-based NIR narrow-band images. In a previous paper, we measured the H2 temperature of knot 51 to be ~3000 K. We present plasma simulations of knot 51 to probe the excitation mechanisms, formation processes and dust content in environments which can produce the observed H2 emission. One interesting viable case has a core that is primarily atomic, with the H2 emission coming from just a trace molecular component. In this unusual situation, H2 forms primarily through associative detachment rather than through the normal grain cataylsis process.

431.13 – **SOFIA/FORCAST Mid-Infrared Observations of the Ultra Compact H II Region W3(OH) and Three Nearby Protostars in W3**

Joseph D. Adams[1], L. Hirsch[1], T. L. Herter[1], S. T. Megeath[2], J. L. Hora[3], J. M. De Buizer[4], G. E. Gull[1], C. P. Henderson[1], L. D. Keller[5], J. Schoenwald[1], W. Vacca[4]
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9:00 AM - 6:30 PM

We present infrared observations of the ultra-compact H II region W3(OH) made with Spitzer/IRAC and SOFIA/FORCAST. We contribute new wavelength data to the spectral energy distribution, which constrains the optical depth, grain size distribution, and temperature gradient of the dusty shell surrounding the H II region. We do not detect the nearby water maser source W3(H2O) at 19.7 - 37.1 microns. Additionally, we present observations of three protostellar objects in the SOFIA W3(OH) field. Models (Robitaille et al. 2007) suggest that two of these sources (2MASS J02270824+6152281, and 2MASS J02270743+6152281) are intermediate-mass protostars with luminosities ~300 - 750 L_sun and ~100 - 250 L_sun, respectively. Model fits to the third source (2MASS J02270887+6152344) have a luminosity range of ~2800 - 4200 L_sun, which is consistent with a young B-type star with an optically thick circumstellar envelope still in its accretion phase.

432 – Supernovae

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

432.01 – **SN2011ht -- Supernova or Impostor?**

Kris Davidson[1], R. M. Humphreys[1], C. S. Kochanek[2], R. W. Pogge[2], J. S. Prieto[3], P. W. A. Roming[4], K. Z. Stanek[2]
[1]Univ. of Minnesota, [2]Ohio State University, [3]Princeton University, [4]Southwest Research Institute.
9:00 AM - 6:30 PM

SN2011ht is a peculiar Type IIn supernova, or conceivably a SN impostor, which exhibited a very rapid rise to maximum in the UV shortly after its discovery. The steep continuum and large UV flux were unusual, especially in combination with the later spectral changes. We describe its spectroscopic and photometric evolution from UV maximum to a rapid decline about 100 days later. The visual spectrum at UV maximum resembled a hot but dense stellar wind. It was dominated by strong Balmer emission lines with prominent Thomson scattering wings, P Cygni type absorption features, peculiar broadened He I emission, and a fairly modest P Cyg Doppler speed. About 80 days after discovery, the spectrum rapidly transitioned from a hot wind to that of a cool dense wind, resembling the absorption line spectrum of an F or G-type supergiant with Balmer and Ca II emission lines. Then the spectrum changed again during its rapid decline. We interpret these changes in terms of shocks interacting with circumstellar ejecta.

432.02 – **Optical and Infrared Analysis of Type II SN 2006bc**

Joseph S. Gallagher[1], B. E. Sugerman[2], G. C. Clayton[3], J. E. Andrews[4], J. Clem[3], M. J. Barlow[5], B. Ercolano[6], J. Fabbri[5], M. Otsuka[7], R. Wesson[5], M. Meixner[8]
[1]University of Cincinnati Blue Ash College, [2]Goucher College, [3]Louisiana State University, [4]University of Massachusetts, Amherst, [5]University College London, United Kingdom, [6]University Observatory Munich, Germany, [7]Academia Sinica, Institute of Astronomy and Astrophysics, Taiwan, [8]Space Telescope Science Institute.
9:00 AM - 6:30 PM

We present nebular phase optical imaging and spectroscopy and near/mid-IR imaging of the Type II SN 2006bc. Observations reveal the central wavelength of the symmetric Halpha line profile to be red-shifted with respect to the host galaxy Halpha emission by day 325. Such a phenomenon has been argued to result from an asymmetric explosion in the iron-peak elements resulting in a larger mass of 56Ni and higher excitation of hydrogen on the far side of the SN explosion. We also observe a gradual blue-shifting of this Halpha peak which is indicative of dust formation in the ejecta. Although showing a normal peak brightness, V ~ -17.2, for a core-collapse SN, 2006bc fades by ~6 mag during the first 400 days suggesting either a relatively low 56Ni yield, an increase in extinction due to new dust, or both. A short duration flattening of the light curve is observed from day 416 to day 541 suggesting an optical light echo. Based on the narrow time window of this echo, we discuss implications on the location and geometry of the reflecting ISM. With our radiative transfer models, we find an upper limit of 2 x 10^-3 solar masses of dust around SN 2006bc. In the event that all of this dust were formed during the SN explosion, this quantity of dust is still several orders of magnitude lower than that needed to explain the large quantities of dust observed in the early universe.

432.03 – **The All Sky Automated Survey for Supernovae (ASsAS-SiN)**

Benjamin Shappee[1], K. Stanek[1], C. Kochanek[1], J. Beacom[1], D. Szczygiel[1], J. Prieto[2], G. Pojmański[3], W. Rosing[4], E. Hawkins[4], R. Ross[4], M. Elphick[4], D. Mullins[4], Z. Walker[4]
[1]The Ohio State University, [2]Princeton University, [3]Warsaw University Observatory, Poland, [4]Las Cumbres Observatory.
9:00 AM - 6:30 PM

The All Sky Automated Survey for Supernovae (ASsAS-SiN) is a long-term project to monitor the whole sky to find nearby supernovae (SNe). Many distant SNe observed by volume-limited surveys, including some of the most interesting events, are seen to occur in the outskirts of galaxies or in dwarf galaxies. Locally, most of these SNe are currently being missed by amateurs and galaxy-targeted SN surveys, but could be detected by an all-sky survey. We are currently commissioning the north ASsAS-SiN unit, Brutus, on Haleakala in Hawaii. Brutus is equipped with two telescopes on a common mount. Each telescope has a 14cm lens and an FLI ProLine CCD camera with a Fairchild Imaging 2k× 2k thinned CCD, giving a 4.47×4.47 square-degree field-of-view, and corresponding to a per pixel image scale of 7.8" per pixel image scale. Las Cumbres Observatory Global Telescope Network (LCOGT) has provided Brutus with a custom equatorial mount as well as site support inside the Faulkes Telescope North enclosure. The early commissioning data is promising, showing that Brutus has a limiting magnitude of V~17.5 mag, and is already providing follow up for nearby SN, including the type IIn SN 2011ht, which exhibited unusual temporal and spectral evolution.

432.04 – **The Final Word on the Progenitor of the Type II-Plateau Supernova SN 2006my**

Douglas C. Leonard[1], Y. Green[2], A. Gal-Yam[2], D. B. Fox[3]
[1]San Diego State University, [2]Weizmann Institute of Science, Israel, [3]Pennsylvania State University.
9:00 AM - 6:30 PM

By registering pre-supernova (pre-SN) and post-supernova (post-SN) images, usually taken at high resolution, roughly three dozen core-collapse supernovae have now had the properties of their progenitor stars either directly measured or (more commonly) constrained by establishing upper limits on their luminosities. Here we reexamine the particularly vexing case of supernova SN 2006my, a classic nearby Type II-Plateau supernova (SN II-P) whose explosion site had been fortuitously imaged by the Hubble Space Telescope (HST) twelve years prior to the explosion, enabling three independent investigations to be carried out. In the first, Li et. al. (2007) reported spatial coincidence between SN 2006my and a (possibly extended) source with properties deemed consistent with those of a red supergiant (i.e., the type of progenitor expected for an SN II-P). Subsequent analyses by Leonard et al. (2008) and Crockett et al. (2010), however, refuted the Li et al. detection claim, but recognized that existing data did not permit a definitive resolution of the issue, since the SN 2006my localizations still placed it on *part* of the putative progenitor's point-spread-function in the pre-SN frames, just no longer at its center. To definitively establish the association/non-association of SN 2006my with the source identified in the pre-SN images, we have acquired new HST images of the site of SN 2006my (long after SN 2006my has faded beyond detection), and here report the final results of our study (i.e., whether any of the proposed progenitor object's light has now disappeared). We also report preliminary results from a similarly carried out investigation into the progenitor of the Type Ib SN 2007fo.

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433 – Spiral Galaxies and the Milky Way

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

433.01 – **The Catalog of Edge-on Disk Galaxies Found in SDSS**

Stefan J. Kautsch[1], D. Bizyaev[2], A. V. Mosenkov[3], N. Y. Sotnikova[4], V. P. Reshetnikov[4], R. W. Hillyer[5], N. V. Yablokova[4]
[1]Nova Southeastern UniversityFarquhar College of Arts and Sciences, [2]Apache Point Observatory / NMSU, [3]St. Petersburg State University and Central Astronomical Observatory of RAS, Russian Federation, [4]St. Petersburg State University, Russian Federation, [5]Christopher Newport University.
9:00 AM - 6:30 PM

We present a catalog of edge-on disk galaxies automatically identified in the seventh data release (DR7) of the Sloan Digital Sky Survey. We made a preliminary quantitative morphological classification of the galaxies and then visually inspected 15225 pre-selected individual objects in g,r,i SDSS bands using the images taken from the eighth SDSS data

release. The inspection reveals that only 40% of all pre-selected objects are bona fide edge-on galaxies, whereas 55% of the objects show features typical for the non edge-on galactic disks. The rest of the sample comprises the galaxies which are not

good for an automatic analysis because of extremely bright stars nearby, numerous foreground stars, strong galactic warps, strongly interacting components, etc. The images of the catalog objects are used to estimate the structural parameters of disks and bulges for more than 6000 true edge-on galaxies in each of the g,r,i photometric bands. Our results from a simple preliminary analysis technique will be ameliorated by applying more realistic radial transfer models in future work on the catalog analysis. Hardware part of our work was partly supported by the AAS Small Research Grant.

433.02 – **Dynamical Models Of Ngc 3124: A Galaxy With An Apparent Counter-winding Bar-spiral Hybrid**

Patrick M. Treuthardt[1], M. Seigar[1], H. Salo[2], D. Kennefick[3], J. Kennefick[3], C. H. S. Lacy[3]

[1]University of Arkansas at Little Rock, [2]University of Oulu, Finland, [3]University of Arkansas.

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. It is clearly observed in the high resolution B, V, R, I, and Ks-band images from the Carnegie-Irvine Galaxy Survey. We present preliminary results of our attempts to recreate the observed gaseous and stellar morphology through test particle simulations.

433.03 – **Constraints on Disk Heating Agents Across the Hubble Sequence**

Kristen L. Shapiro[1], J. Gerssen[2]

[1]Northrop Grumman Aerospace Systems, [2]Leibniz-Institut fuer Astrophysik Potsdam, Germany.

9:00 AM - 6:30 PM

We measure the shape of the stellar velocity ellipsoid in two late-type spiral galaxies (Hubble types Sc and Scd) and combine these results with our previous analyses of six early-type spirals (Sa to Sbc) to probe the relation between galaxy morphology and the ratio of the vertical and radial dispersions. We confirm at much higher significance (99.9) our prior detection of a tight correlation between these quantities. We explore the trends of the magnitude and shape of the velocity ellipsoid axes with galaxy properties (color, gas surface mass density, and spiral arm strength). The observed relationships allow for an observational identification of the radial and vertical disk heating agents in external disk galaxies.

433.04 – **Determination of Resonance Locations in a sample of Barred Spiral Galaxies**

Amber Sierra[1], M. S. Seigar[1], P. Treuhardt[1], T. Mears[1], I. Puerari[2]

[1]University of Arkansas at Little Rock, [2]Instituto Nacional de Astrofisica, Optica y Electronica, Mexico.

9:00 AM - 6:30 PM

We have selected a sub-sample of ground-based ugriz band images of face-on barred spiral galaxies from the EFIGI galaxy survey. We take Fourier transforms along radial cuts in all wavebands and compare the phase angles as a function of radius between them. The radius at which the phase angles cross indicates the location of the corotation radius. We compare this with previously determined locations of the corotation radii (where available) using various alternative methods.

433.05 – **Systematic Problems With Stellar Halo Modelling**

Jeremy Bailin[1]

[1]University of Michigan.

9:00 AM - 6:30 PM

Stellar halos contain a small fraction of the stellar mass of a galaxy. The dynamic range required to model the substructure within this small component while simultaneously modeling the main galaxy is currently unobtainable, which has lead to the prevalence of stellar halo models that tag stellar content onto dark matter particles in pure dark matter simulations, making it computationally feasible (e.g. Bullock & Johnston 2005; Cooper et al. 2010). Using paired simulations with identical initial conditions, we estimate the magnitude of the systematic effects these simplifications have on the structure of the halos. We find that (1) "painting" and (2) neglecting baryonic processes each introduce factor-of-several changes to the amount of substructure predicted. We therefore urge caution when interpreting differences between models and observations that are at this level.

433.06 – **A Comparison of Four Methods for Measuring Supermassive Black Hole Masses**

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

We present a study of 60 galaxies using Spitzer/IRAC 3.6 μm images and applying the correlations between supermassive black hole (SMBH) masses, and the distribution of host galaxy properties (bulge luminosity or bulge stellar velocity dispersion), maximum rotation velocity, and pitch angle. We determine pitch angles using a 2D Fast Fourier Transform decomposition technique, the bulge luminosity using a 2-D surface brightness profile modeling routine, and we take velocity dispersions and maximum rotation velocities from the literature. These methods provide a separate determination of SMBH mass for each galaxy.

433.07 – **Bars And Agn Activity**

Myung Gyoon Lee[1], G. Lee[1], J. Woo[1], H. Hwang[2], J. Lee[3], J. Sohn[1], J. Lee[1]

[1]Seoul National Univ., Korea, Republic of, [2]Smithsonian Astrophysical Observatory, [3]Korea Astronomy and Space Science Institute, Korea, Republic of.

9:00 AM - 6:30 PM

Bars are often found in active galaxies. It was suggested long ago that bars may play a significant role in triggering activity in AGN. However, the results from recent studies on this issue are controversial. We investigate the connection between the presence of bars and AGN activity, using a large volume-limited sample of galaxies in the Sloan Digital Sky Survey. Our sample includes about 9,000 late-type bright galaxies at low redshift z=0.02 to 0.055. It is found that the bar fraction in AGN-host galaxies is 2.5 times higher than in non-AGN galaxies, and that the AGN fraction is a factor of two higher in strong-barred galaxies than in non-barred galaxies. However, these trends are simply caused by the fact that AGN-host galaxies are on average more massive and redder than non-AGN galaxies. In addition, we find no significant difference in the Eddington ratio distributions between barred and non-barred systems among AGN-host galaxies. These results show that AGN activity is not dominated by the presence of bars, and that AGN power is not enhanced by bars. In conclusion there is no clear evidence that bars trigger AGN activity.

433.08 – **The EDGES Survey: Searching for Faint Stellar Distributions**

Liese van Zee[1], D. A. Dale[2], K. L. Barnes[1], S. Staudaher[2], D. Calzetti[3], J. J. Dalcanton[4], J. S. Bullock[5], R. Chandar[6]

[1]Indiana Univ., [2]University of Wyoming, [3]University of Massachusetts, [4]University of Washington, [5]University of California, Irvine, [6]University of Toledo.

9:00 AM - 6:30 PM

We present preliminary results from the Extended Disk Galaxy Exploration Science (EDGES) Survey currently underway with the Spitzer Space Telescope. This Exploration Science program will image 92 galaxies spanning a wide range of morphology, luminosity, and environment. Our wide field-of-view observations at 3.6 micron allow us to trace substructures out to 5 times the optical radius and are sensitive to surface mass densities of a few hundredths of a solar mass per square parsec. We present analysis of a representative field to illustrate the sensitivity and depth of the survey data.

433.09 – **An Update of HIGGS: The Herschel Inner Galaxy Gas Survey**

Allison P. M. Towner[1], C. L. Martin[2], HIGGS Team

[1]The University of Arizona, [2]Oberlin College.

9:00 AM - 6:30 PM

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. 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. This poster will present recent Herschel HIGGS observations and results from our ongoing analysis.

433.1 – **The Smith Stream: A High Velocity Cloud crossing the Milky Way Disk**

Felix J. Lockman[1]

[1]NRAO.

9:00 AM - 6:30 PM

The Smith Cloud is a high-velocity HI cloud with the following extraordinary properties: it is located about 12 kpc from the Sun but less than 8 kpc from the Galactic Center, and it's tip is currently about 2 kpc below the Galactic plane. Its complete space motion is known and it is on a trajectory to cross the Galactic plane in about 30 Myr. Its size is >3 x >1 kpc, and it contains more than two million solar masses of ionized and neutral Hydrogen. Recent new HI observations with the NRAO Green Bank Telescope have revealed a series of small HI clouds over an area ahead of the Smith Cloud that have kinematics and locations consistent with following the same trajectory as the Cloud. Their spectra suggests that they are interacting strongly with the local ISM. The implication is that that the Smith Cloud is the largest object along a stream of gas more than 6 kpc in extent, some of which has already passed through the Galactic plane.

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434 – Starburst Galaxies

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

434.01 – **Star formation in Kiso measle galaxies**

Debra M. Elmegreen[1], B. G. Elmegreen[2]

[1]Vassar College, [2]IBM T.J. Watson Research Ctr..

9:00 AM - 6:30 PM

The Kiso sample of several thousand local ultraviolet-bright galaxies includes galaxies classified as irregular disk galaxies with large star-forming complexes (I,g). We selected a sample of all I,g galaxies with both Sloan Digital Sky Survey images and spectra. They contain up to several dozen giant clumps each, so we refer to them as measle galaxies. We determined ages and masses of the clumps based on a comparison of photometry with population synthesis models of cluster evolution. The spectra were used to determine global star formation rates. Several hundred clumps were measured in the sample, with masses ranging from 10^5 to several x10^8 solar masses, scaling with galaxy absolute g magnitude of -14 to -21 mag. The galaxies are starbursting, sitting above the Groth strip “main sequence” of star formation rate versus galaxy mass by an order of magnitude. These Kiso measle galaxies have 10x the star formation rates of the Kiso tadpole galaxies. We compare their clump luminosity distribution functions with normal disk galaxies.

434.02 – **Kinematics of Cool Clouds in Realistic Galaxy Winds**

Edward Cheng[1], M. Wojtaszek[1], J. Everett[1]
[1]*University of Wisconsin - Madison.*
9:00 AM - 6:30 PM

Observations of starburst galaxy winds have detected neutral gas clouds outflowing at speeds on the order of 100 km/s. Given the difficulties in determining velocities accurately using x-ray observations, these clouds have the potential to be extremely useful as tracers in determining the velocity of the hot gas winds using optical measurements. However, the velocity profiles of clouds in a pressure-driven wind are not well understood. Furthermore, forces such as ram pressure and radiation pressure act to destroy the gas clouds, potentially reducing the usefulness of the clouds as tracers.

Using realistic kinematic profiles produced from a high temperature, pressure-driven galactic-wind model, we calculate the kinematics of cool clouds within the winds due to ram pressure. We also calculate the effects of radiation pressure on the clouds and mass loss due to the interaction of the clouds within the wind. In particular, we apply our model to cool gas clouds in M82 and vary the initial conditions of mass, volume, and injection height of the gas clouds to understand the conditions under which clouds are successfully launched and accelerated.

This project was supported by the National Science Foundation grant AST-1109218.

434.03 – **Cosmic Rays in M82: Testing the Calorimeter Model**

Tova Yoast-Hull[1], J. Everett[1], J. S. Gallagher, III[1], E. Zweibel[1]
[1]*University of Wisconsin-Madison.*
9:00 AM - 6:30 PM

From first principles, we construct a simple model for the evolution of energetic particles in the starburst galaxy M82. Assuming constant cosmic-ray acceleration efficiency with Milky Way parameters, we calculate the cosmic-ray proton and primary & secondary electron/positron populations. From the cosmic-ray spectra, we can predict the radio synchrotron and gamma-ray spectrum. To more accurately model the radio spectrum, we incorporate a multiphase interstellar medium in the starburst region of M82. The interstellar medium is highly fragmented with compact dense molecular clouds and dense ionized gas, both embedded in a hot, low density medium in overall pressure equilibrium. The spectra for this simple model are compared to the observed radio and gamma-ray spectra of M82. Chi-squared tests are used to compare with radio observations to find the best-fit parameters. The best-fit model yields constraints on the magnetic field strength for the starburst zone in M82. Through this project, we aim to check the calorimeter model, in which energetic particles lose most of their energy within the galaxy, and build a better understanding of the radio-FIR correlation in starburst galaxies.

434.04 – **Predicting Neutral-Cloud Absorption Line Profiles in Galactic Winds**

Michelle Wojtaszek[1], E. Cheng[1], J. Everett[1]
[1]*UW Madison.*
9:00 AM - 6:30 PM

We present theoretical predictions for NaI lines produced in cool clouds entrained in galactic winds (GWs), calculated for hydrogen column densities and temperatures appropriate to cool clouds above starburst galaxies. We focus on lines that are observed in the outflows from starburst galaxies because we wish to constrain GWs, which are important to a variety of astrophysical phenomena and possibly to the formation of large-scale cosmological structure. NaI lines in the spectra of starburst galaxies can be used to extract properties of cool gas entrained in the GWs. Our group has developed a semi-analytical model of large-scale GWs to calculate the acceleration of the hot-gas component of these winds, and in addition, to calculate the acceleration of cool clouds within the wind (see poster by E. Cheng). The work presented here uses the physical parameters of clouds, derived from these models, in conjunction with the stellar population modeling software Starburst99 and the photoionization code Cloudy. Together, these allow us to predict the NaI line shapes expected to occur in cool clouds entrained in GWs, and specifically, line shapes for the prototypical starburst galaxy M82. In the future, comparing these line shapes with observations will help us understand and constrain the physical mechanisms that drive such large-scale winds.

This work was supported by the National Science Foundation grant AST-1109218.

434.05 – **Probing the Ionized Medium in Early Universe with ZEUS(1 & 2)**

Carl Ferkinhoff[1], D. Brisbin[1], T. Nikola[1], S. Parshley[1], G. Stacey[1], S. Hailey-Dunsheath[2], T. G. Phillips[3], E. Falgarone[4], D. Benford[5], J. Staghun[5], K. Irwin[6], S. Cho[6], M. Niemack[6]
[1]*Cornell University,* [2]*JPL,* [3]*Caltech,* [4]*3 LERMA, CNRS, Observatoire de Paris and ENS, France,* [5]*Goddard Space Flight Center,* [6]*NIST Boulder.*
9:00 AM - 6:30 PM

Using the first generation Redshift(z) and Early Universe Spectrometer (ZEUS-1) on the Caltech Submillimeter Observatory we made the first detections of the [NII] 122 μm and [OIII] 88 μm lines from galaxies in the early Universe. We detect both lines from SMMJ02399-0136 at z ~ 2.8, while from H1413+117 (the Cloverleaf QSO) at z~2.6 and APM08279+5255 at z~3.9 we detect only the [NII] and [OIII] lines respectively. All three sources are lensed, IR-luminous with intrinsic far-infrared (FIR) luminosities $>10^{12}$ L_{sun}, and contain both an active galactic nucleus (AGN) and star-forming component. The lines detected from the sources are bright with line to FIR continuum luminosity ratios ranging between $\sim 5\times10^{-4}$ and $\sim 2\times10^{-3}$. The [NII] and [OIII] lines are excellent probes of the state of the ionized gas. The strengths of the lines provide a minimum ionized-gas mass, which for our sources is large, ~8%-17% of the molecular gas mass. The ratio of the lines is very sensitive to the effective temperature of ionizing stars and the ionization parameter for emission arising in the narrow-line region (NLR) of an AGN. The [OIII]/[NII] line ratio for SMMJ02399 indicates that the dominant source of the line emission is either stellar H II regions ionized by O9.5 stars, or the NLR of the AGN with ionization parameter log(U) = -3.3 to -4.0. Both the Cloverleaf and APM08279 exhibit starbursts similar to that found in M82 and are respectively best modeled by a superposition of ~200 and ~270 M82 like starbursts. Follow-up observations with Herschel and ALMA, will constrain the fraction of line emission arising in the starburst and NLR. Using ZEUS-2 (Ferkinhoff et al. 2010) we will expand our sample of high-redshift galaxies with [NII] and [OIII] detections to fully understand the state and evolution of ionized medium in the early Universe.

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435 – Galaxy Clusters

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

435.01 – **The Outskirts Of Galaxy Clusters: To r200 And Beyond With Suzaku, Xmm-newton And Chandra**

Jithin V. George[1], R. Mushotzky[2], E. D. Miller[3], M. Bautz[3], D. Davis[4], J. Henry[5]
[1]*University of Maryland,* [2]*University of Maryland / GSFC,* [3]*MIT Kavli Institute for Astrophysics and Space Research,* [4]*CRESST and X-ray Astrophysics Laboratory, NASA/GSFC,* [5]*University of Hawaii.*
9:00 AM - 6:30 PM

Galaxy clusters are the largest gravitationally bound structures in the universe and thus provide the best opportunity to study cosmology at work. Their outskirts, regions close to the virial radius, have not been well studied and could aid in our understanding of cluster growth, structure and mass. We show results from a program to constrain the properties of the outer intra-cluster medium in a sample of galaxy clusters, making use the strengths of the three complementary X-ray observatories: Suzaku which has a low and stable background, XMM-Newton which has a very high sensitivity, and Chandra which provides good spatial resolution. The sample comprises eleven mostly relaxed clusters at z~0.1-0.2 with full azimuthal coverage to beyond r_{200}. Here we report results, obtained with our new analysis method, on the cluster RXCJ0605. We are able to measure diffuse X-ray emission well beyond r_{200}. Our results suggest that the ICM is not in hydrostatic equilibrium in the outskirts of this cluster: we detect clear azimuthal variations in temperature and surface brightness. We are extending this analysis for our sample of galaxy clusters and thus will produce a sizable data set for detailed comparison with numerical simulations.

435.02 – **A Spectroscopic Study of Fossil Group Systems: Are Fossil Groups Truly Fossilized?**

Hanna Herbst[1], E. Wilcots[1], K. Hess[1], C. Gerhartz[1], J. Kaczmarek[1]
[1]*University of Wisconsin.*
9:00 AM - 6:30 PM

The majority of nearby galaxies reside in galaxy groups, where the internal velocities of the member galaxies are comparable to the velocity dispersion of the group, conditions that are conducive to galaxy merging. Simulations (Dariush et al. 2007, 2010) suggest that merging within galaxy groups will lead to a giant, relatively isolated elliptical galaxy, termed a fossil group. While fossil groups are unique objects that have the potential to answer many questions about galaxy evolution, we know little about the dynamics of the fossil group environment. Here we present the results from a spectroscopic study of eight fossil group systems and their environments using the Hydra multifiber instrument on the WIYN 3.5m telescope. For each configuration, we obtain spectra for approximately 70 galaxies. For each fossil group system, we use the velocity distribution of the galaxies to determine the dynamical mass of the fossil group and explore the possible infall of new members and the extent to which fossil groups are truly dynamically relaxed.

435.03 – **The Masses and Bulk Velocities of Galaxy Clusters in Simulations of Structure Formation with QMOND**

Stacy S. McGaugh[1], H. Katz[1], P. Teuben[1], G. Angus[2]
[1]*Univ. of Maryland,* [2]*Univ. of Cape Town, South Africa.*
9:00 AM - 6:30 PM

We investigate the formation of large scale structure in the quasi-linear formulation of MOND (QMOND). Two intriguing features emerge. Massive clusters (> 1E15 solar masses) emerge at z ~ 1, developing substantial bulk velocities (> 1,000 km/s) by z ~ 0. This might provide a natural explanation for the existence of very massive clusters like El Gordo, and for the large cluster bulk velocities observed by Kashlinsky et al. High speed collisions like the Bullet cluster are considerably less improbable than they are in LCDM.

435.04 – **The Metal Abundance of High-Redshift Galaxy Clusters with Suzaku**

Eric D. Miller[1], M. Bautz[1], W. Forman[2], C. Jones[2], B. Benson[3], D. Marrone[4], C. Reichardt[5], F. W. High[3], M. Brodwin[6], J. Carlstrom[3]

[1]MIT, [2]SAO/CfA, [3]U. Chicago, [4]U. Arizona, [5]UC Berkeley, [6]U. Missouri, Kansas City.

9:00 AM - 6:30 PM

The metal enrichment history of the intra-cluster medium (ICM) encodes the history of star formation, the evolution of cluster galaxies, and the interactions between those galaxies and the intergalactic medium. Measuring cluster metal abundance as a function of redshift can constrain models of these processes, however until recently such measurements have been complicated by a lack of detected high-redshift clusters and by the low X-ray flux of such distant clusters. The advent of surveys exploiting the Sunyaev-Zel'dovich (SZ) effect has begun to greatly expand the number of high-redshift clusters available for study. One such project, the South Pole Telescope (SPT) cluster survey, has resulted in a uniquely high median redshift (<z> = 0.74) among cluster samples, and this presents an opportunity to trace the evolution of ICM metal enrichment to high redshift.

We here present Suzaku X-ray Observatory observations of four clusters at z = 0.7-1.1 which have been identified by the SPT cluster survey. These high-quality data allow among the most precise measurements of the ICM metal abundance to date at these redshifts: we find Fe abundances in the range 0.26-0.45 solar, with 1-σ uncertainties of 25-30%. These enhanced metal abundances are in tension with simulations that predict a decrease in Fe abundance of 50% from the local universe to z ~ 1, and compared to previous results they point to a significant variation in cluster metallicity at early times. We discuss the possible implications of these results on metal enrichment models and future prospects for greatly expanding the sample of high-redshift clusters with high-quality metal abundance measurements.

435.05 – **A Recent Cluster Merger Bent the Radio Source in Abell 562**

Percy L. Gomez[1]

[1]Gemini Obs., Chile.

9:00 AM - 6:30 PM

We confirm that the physical mechanism responsible for the bending of the radio jets in Abell 562 is a recent cluster merger. It has been proposed that radio jets in wide-angle tailed radio sources (WATs) bend by ram pressure between the jets and the intra-cluster medium (ICM). A new ram pressure model for A562 suggests that a velocity of about 800 km/s is needed for bending its radio jets. We verified that a recent merger happened in this cluster by analyzing over 100 new redshifts for the cluster members. Moreover, we also verified that the radio galaxy has negligible peculiar velocity. Finally, our ram pressure calculations at the points of jet bending derived from the velocity and X-ray data support this model.

435.06 – **Enhanced Specific Star Formation along the Filament feeding the Cluster Abell 85.**

Dario Fadda[1], F. Durret[2], L. Edwards[3]

[1]Caltech, [2]IAP, France, [3]Mount Allison University, Canada.

9:00 AM - 6:30 PM

We report the analysis of optical spectra and near-infrared images of the galaxies in the system composed by the cluster Abell 85 and a filament feeding it from the South. The filament has been discovered by our team using X-ray observations. In the last couple of years, in order to study dynamical and star formation properties, we observed an area of approximately one square degree in the near-IR and obtained spectra for more than 500 member galaxies of the cluster and the filament. These data complement available public images and spectra from the Sloan Digital Sky Survey. Our analysis of the member galaxies reveals a dramatic enhancement of the specific star formation along the filament feeding the cluster and inside a group of galaxies identified in the X-ray images as the Southern blob.

435.07 – **Chandra Study of the Ultra-Steep Spectrum Radio Relic Cluster Abell 2443**

Tracy E. Clarke[1], S. Randall[2], C. Sarazin[3], E. Blanton[4]

[1]Naval Research Lab., [2]CFA, [3]University of Virginia, [4]Boston University.

9:00 AM - 6:30 PM

Low frequency (74 MHz) observations from the VLA Low Frequency Sky Survey (VLSS) revealed the presence of ultra-steep spectrum (USS) radio emission in the cluster Abell 2443. Follow-up radio studies confirmed the presence of extended diffuse radio emission in the system (Cohen & Clarke 2011). We present new Chandra observations of Abell 2443 which reveal clear evidence of an on-going merger. The intracluster medium shows several interesting features including a possible ram-pressure stripped tail to the north, a cold-front edge to the northeast, and a potential shock edge to the southeast which is coincident with the relic emission. If the shock is confirmed, this would only be the fifth known radio relic with an associated X-ray shock and the second such system which contains a rare USS relic. We discuss the potential implication of this connection for particle acceleration in radio relics and the power of such systems for identifying dynamically disturbed merging systems. We briefly discuss the potential for detecting many new USS relic systems with the upcoming generation of low frequency interferometers including the new low band radio receivers being developed for the NRAO EVLA.

Basic research in radio astronomy at the Naval Research Laboratory is supported by 6.1 base funding. Support for this work was provided by the National Aeronautics and Space Administration, through Chandra Award Number GO1-12007Z.

435.08 – **The Importance of High-Mass Stars for Metal Enrichment in Galaxy Clusters**

Caitlin Heath[1], B. J. Morsony[2], J. C. Workman[1]

[1]Colorado Mesa University, [2]University of Wisconsin.

9:00 AM - 6:30 PM

Galaxy clusters contain more metal per star than would be expected from a standard stellar initial mass function. We set out to determine what modifications are needed to reproduce the observed metal enhancement. Modifications include expanding the IMF to high mass (>130 M_sun) stars and including metal production from pair-instability supernovae, a higher binary fraction leading to an enhanced type Ia SN rate, and modifying the IMF to make it more top-heavy. For each set of assumptions, we use theoretical nucleosynthesis models to calculate the expected total metal yield per mass of star formation, and the predicted ratios between different elements.

435.09 – **Cool Cores In Galaxy Clusters: How Do They Work?**

Jack O. Burns[1], S. Skory[1], E. Hallman[1], S. Skillman[1]

[1]Univ. of Colorado at Boulder.

9:00 AM - 6:30 PM

Surveys of rich galaxy clusters, such as the flux-limited HIFLUGCS, show that about half of clusters have so-called cool cores (CCs). In comparison to non-cool cores (NCCs), CCs have peaked central X-ray emission, short central cooling times (<0.1 of the Hubble time), and central temperatures ~30% of the virial temperature. We have previously simulated clusters using the cosmological N-body + Eulerian hydrodynamics code Enzo which reproduce some of the observed properties. However, these simulations, and those of other groups, fall short in some important respects, most notably bulk quantities such as central entropy and cooling time, and CC fraction. In this work, we apply two new physical models that partially address the shortcomings. We add distributed stellar feedback which deposits thermal and metal feedback from stars over a wider volume than before, and we use CLOUDY cooling which employs metallicity-dependent gas cooling. We find that these additions allow us to simulate clusters with more realistic central cooling times, entropies, and temperature drops. However, other aspects of the clusters remain unimproved, such as star formation histories and overall CC fraction. In this poster, we compare the simulated and observed properties of galaxy clusters, the successes and the shortcomings of our simulations, and describe another approach using more realistic distributed feedback and observationally-driven star formation rates.

435.1 – **Matter Substructure in High Redshift Clusters of Galaxies**

Paul M. Huwe[1]

[1]Brown University.

9:00 AM - 6:30 PM

We investigate substructure via weak gravitational lensing shear measurements of high redshift clusters with existing ACS imaging. We use a principal component analysis technique to characterize the PSF ellipticity pattern and a variable aperture filter to characterize the level of substructure. This work supported by the NASA Rhode Island Space Grant program.

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436 – Cosmology & Cosmic Microwave Background

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

436.01 – **Weak Lensing Magnification using a Photometric Fundamental Plane**

Genevieve Graves[1], E. M. Huff[1]

[1]Univ. of California at Berkeley.

9:00 AM - 6:30 PM

Weak lensing (WL) suffers from a paucity of signal, where high-quality imaging, large statistical samples, and the painstaking correction of systematic errors are critical to making reliable measurements of the distribution of dark matter. We have recently developed a new method for weak lensing using background source magnification instead of using gravitational shear. Traditional magnification methods have struggled to match the signal-to-noise (S/N) per background source achieved by shear because the intrinsic dispersion of galaxy luminosities and radii are much larger than the intrinsic dispersion of ellipticities. We have solved this problem using knowledge about the galaxy population to predict the intrinsic radii to within ~ 40%. Our new magnification method thus yields a signal that is nearly comparable to shear. Moreover, the dominant sources of systematic error are different from those in shear-based measurements. This means that combining shear and magnification can alleviate the worst biases in each method and produce a substantially more robust, higher S/N measurement of the dark matter distribution for a given survey than can be achieved with shear alone. As a proof-

of-concept, we have used this technique to make a galaxy-galaxy lensing measurement using SDSS imaging and spectroscopic data. This talk will describe the new method, and present our first lensing measurements.

436.02 – **Refsdal's Dream Frustrated by Cosinusoidal Potential?**

David F. Bartlett[1], J. P. Cumalat[1]

[1]*Univ. of Colorado.*

9:00 AM - 6:30 PM

In 1964 Sjur Refsdal introduced a new technique: the determination of both the Hubble constant and the mass of a galaxy by the observation of two images formed when the galaxy deflects light from a more distant supernova. Refsdal's technique requires that both the location of the two images be known and also the time delay between the two images. Additionally the galaxy must be spherically symmetric and the line of sight from us to the supernova be only slightly displaced from the line of sight to the galaxy.

Today we recognize Refsdal's work as strong gravitational lensing discovered by Walsh, Carswell, and Weyman in 1979. Refsdal's simple dream is still to be realized.

We believe that the basic problem is not the arbitrariness in placing dark matter but rather that dark matter is not required. To get the correct bending of light around a spherical galaxy one cannot simply double the Newtonian result. Instead one must use as a basis the Cosinusoidal Potential, V=-(GM/R) cos[koR]; ko=2 pi/400 pc .

We present an explanation and examples.

436.03 – **Faraday Rotation due to Magnetic Fields in the Cosmic Web**

Dongsu Ryu[1], T. Akahori[2]

[1]*Chungnam National University, Korea, Republic of,* [2]*Korea Astronomy and Space Science Institute, Korea, Republic of.*

9:00 AM - 6:30 PM

Measuring Faraday rotation would be a promising method to explore magnetic fields in the cosmic web. We investigated the Faraday rotation measure (RM) due to the intergalactic magnetic field (IGMF), using a model IGMF predicted with turbulence dynamo in the cosmic web. The inducement of RM is a random walk process, and the probability distribution of |RM| is log-normal. The root mean square (rms) of RM through a single filament in the local universe is of order ~ 1 radian/square-meter. By integrating up to redshift z = 5, the rms of RM though a number of filaments is ~ several radian/square-meter. The power spectrum of RM has a broad plateau over angular scales of ~ 1 - 0.1 degree with a peak close to ~ 0.1 degree. The second-order structure function has a flat profile in angular separations of > ~ 0.2 degree. The RM due to the galactic magnetic fields, even towards the poles, should be as large as the extragalactic RM. We suggest a strategy to separate the extragalactic RM from the galactic RM in observations.

436.04 – **Intergalactic Magnetic Field and Arrival Direction of Ultra-High-Energy Iron Nuclei**

Hyesung Kang[1], S. Das[2], D. Ryu[3]

[1]*Pusan National Univ., Korea, Republic of,* [2]*Indian Institute of Technology Guwahati, India,* [3]*Chungnam National Univ., Korea, Republic of.*

9:00 AM - 6:30 PM

We have studied how the intergalactic magnetic field (IGMF) affects the propagation of super-GZK iron nuclei that originate from extragalactic sources within the local GZK sphere. Toward this end, we set up hypothetical sources of ultra-high-energy cosmic-rays (UHECRs), virtual observers, and the magnetized cosmic web in a model universe constructed from cosmological structure formation simulations. We then arranged a set of reference objects at high density region to represent astronomical objects formed in the large scale structure (LSS).With our model IGMF, the paths of UHE iron nuclei are deflected on

average by about 70 degrees, which might indicate a nearly isotropic distribution of arrival directions. However, the separation angle between the arrival directions and the nearest reference object on the LSS is only <S>~6 degrees, which is twice the mean distance to the nearest neighbors among the reference objects. This means that the positional correlation of observed UHE iron events with their true sources would be erased by the IGMF, but the correlation with the LSS itself is to be sustained. We discuss implications of our findings for correlations studies

of real UHECR events.This research 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).

436.05 – **CANDELS Results on High-Redshift Active Galactic Nuclei**

Anton M. Koekemoer[1], J. Donley[1], N. A. Grogin[1], N. P. Hathi[2], D. D. Kocevski[3], R. A. Lucas[1], K. P. Nandra[4], J. Trump[3], C. Conselice[5], S. M. Faber[3], H. C. Ferguson[1], R. R. Chary[6], CANDELS Team

[1]*STScI,* [2]*OCIW,* [3]*UCSC,* [4]*MPE, Germany,* [5]*University of Nottingham, United Kingdom,* [6]*Caltech.*

9:00 AM - 6:30 PM

Results on active galactic nuclei at early epochs are presented from the CANDELS survey, which combines deep HST optical+IR imaging over both GOODS fields as well as AEGIS, COSMOS, and the UDS. The extensive additional multi-wavelength coverage on these fields from Chandra, XMM, Spitzer, Herschel, and other facilities 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 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.

436.06 – **Simulation of Cosmic Microwave Background Map Reconstruction with Large Asymmetric Beams**

Robert Lee[1], E. F. Bunn[1]

[1]*University of Richmond.*

9:00 AM - 6:30 PM

The production of new instruments to measure the cosmic microwave background (CMB) involves simulation of instrument design. The goal of our research is to test the effect of different sky scan and beam patterns on intensity and polarization measurements, with particular emphasis on the effect of correlated noise on the reconstructed maps.

The two types of scan patterns we have researched thus far are the simple scan and the pie-slice scan. For the simple scan, we assume an instrument with a compact beam pattern, which sweeps the sky slowly in latitude and quickly in longitude, forming a raster-style scan pattern. The pie-slice scan assumes an instrument with a large wedge-shaped beam consisting of all points with $0<\varphi<\delta\varphi$ and $0<\theta<\pi/2$. The "center" of the beam (i.e., the point of the wedge) scans the sky slowly in a great circle, while the orientation of the beam about its center rotates quickly.

We have used the MADmap software to successfully reconstruct simulated intensity maps and to examine the effects of correlated noise. Future work will quantify the noise properties of the reconstructed maps, extend the simulations to include polarization, and experiment with a variety of beam patterns and scan strategies.

436.07 – **Polarization Predictions for Cosmological Models with Broken Isotropy**

Qingyang Xue[1], E. F. Bunn[1]

[1]*University of Richmond.*

9:00 AM - 6:30 PM

There are anomalies in the large-angle cosmic microwave background data that do not adhere to the standard cosmological model. Because these anomalies are quantified only via a posteriori statistics, their significance is disputed. The way to resolve this problem is to make predictions for future data sets that probe similar scales.

The goal of this research is to find a non-standard model that explains the CMB anomalies, and predict the pattern in the CMB polarization map. We focus in particular on the lack of large-scale fluctuations as quantified by the two-point correlation function, which shows essentially zero correlation on angles greater than about 30 degrees.

We examine a model to explain the lack of large-scale correlations by introducing a "modulating field" to modulate the long-wavelength fluctuations. By simulation we find that the model provides a better fit to the temperature correlation function. We then simulate polarization maps using the same model and examine similar statistics to those used to quantify the lack of large-scale correlations. By finding polarization statistics that predict different values in the standard and non-standard models, we can make a clean a priori prediction for future polarization data sets.

437 – Astronomy Education & Public Outreach

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

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

Susanna Kohler[1], L. M. Weiss[2], C. M. Faesi[3], Astrobites Team

[1]*University of Colorado Boulder,* [2]*UC Berkeley,* [3]*Harvard 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 located at diverse institutes around the country and Europe. 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 and recent readership statistics.

437.02 – **Undergraduate Research at SETI in Astrobiology**

Monika Kress[1], C. Phillips[2], E. DeVore[2], O. Hubickyj[1]

[1]*San Jose State Univ.,* [2]*SETI Institute.*

9:00 AM - 6:30 PM

The SETI Institute and San Jose State University (SJSU) have begun a partnership (URSA: Undergraduate Research at the SETI Institute in Astrobiology) in which undergraduate science and engineering majors from SJSU participate in research at the SETI Institute during the academic year. We are currently in our second year of the three-year NASA-funded grant. The goal of this program is to expose future

scientists, engineers and educators to the science of astrobiology and to NASA in general, and by so doing, to prepare them for the transition to their future career in the Silicon Valley or beyond. The URSA students are mentored by a SETI Institute scientist who conducts research at the SETI Institute headquarters or nearby at NASA Ames Research Center. The SETI Institute is a private, nonprofit organization dedicated to scientific research, education and public outreach. Its mission is to explore, understand and explain the origin, nature and prevalence of life in the universe. SJSU is a large urban public university that serves the greater Silicon Valley area in California. Students at SJSU come from diverse ethnic, cultural and socioeconomic backgrounds. Many of them face financial pressures that force them to pursue part-time work. URSA students are paid to work for 10 hours/week during the academic year, and also participate in monthly group meetings where they practice their presentation skills and discuss future plans. We encourage underserved and underrepresented students, including women, minority, and those who are the first in their family to go to college, to apply to the URSA program and provide ongoing mentoring and support as needed. While preparing students for graduate school is not a primary goal, some of our students have gone on to MS or PhD programs or plan to do so. The URSA program is funded by NASA EPOESS.

437.03 – **Using Group Research Projects to Stimulate Undergraduate Astronomy Major Learning**

Allison M. McGraw[1], K. K. Hardegree-Ullman[1], J. D. Turner[1], Y. L. Shirley[1], A. M. Walker-LaFollette[1], A. N. Robertson[1], T. M. Carleton[1], B. M. Smart[1], A. P. M. Towner[1], S. C. Wallace[1], C. W. Smith[1], L. C. Small[1], M. J. Daugherty[1], B. C. Guvenen[1], B. E. Crawford[1], C. L. Austin[1], W. M. Schlingman[1]
[1]*The University of Arizona.*
9:00 AM - 6:30 PM

The University of Arizona Astronomy Club has been working on two large group research projects since 2009. One research project is a transiting extrasolar planet project that is fully student led and run. We observed the transiting exoplanets, TrES-3b and TrES-4b, with the 1.55 meter Kupier Telescope in near-UV and optical filters in order to detect any asymmetries between filters. The second project is a radio astronomy survey utilizing the Arizona Radio Observatory 12m telescope on Kitt Peak to study molecular gas in cold cores identified by the Planck all sky survey. This project provides a unique opportunity for a large group of students to get hands-on experience observing with a world-class radio observatory. These projects involve students in every single step of the process including: proposal writing to obtain telescope time on various Southern Arizona telescopes, observing at these telescopes, data reduction and analysis, managing large data sets, and presenting results at scientific meetings and in journal publications. The primary goal of these projects is to involve students in cutting-edge research early on in their undergraduate studies. The projects are designed to be continuous long term projects so that new students can easily join. As of January 2012 the extrasolar planet project became an official independent study class. New students learn from the more experienced students on the projects creating a learner-centered environment.

437.04 – **Changing the Face of Astronomy Through Authentic Research Experiences**

K. A. Coble[1], **K'Maja Bell**[2], J. Jafri[3], G. Lyon[3], M. Hammergren[4]
[1]*Chicago State University,* [2]*Mother McAuley High School,* [3]*Project Exploration,* [4]*Adler Planetarium.*
9:00 AM - 6:30 PM

Project Exploration is a Chicago-based science outreach organization that works to ensure communities traditionally overlooked by science, particularly minority youth and girls, have access to personalized experiences with science and scientists. 85% of students participating in Project Exploration come from low-income families, primarily African-American and Latino, and 74% are girls. We particularly target students who may not be academically successful. The results of a recent 10-year retrospective study demonstrate that Project Exploration students are significantly more likely than their peers to graduate from high school (95%), go to college (50%), and major in science (60%); and they attribute their persistence in science and education to their Project Exploration experience. Furthermore, Project Exploration works with the scientists involved (including graduate students and post-docs) to help them understand what it means to do effective educational outreach and how to put the interests of the youth at the center of outreach work. In this poster, we describe the details of the Project Exploration model, as well as several projects in astronomy that our students and scientists have carried out. KB and KC are supported by NASA ROSES E/PO Grant #NNX1OAC89G. KC is also supported by the Illinois Space Grant Consortium.

437.05 – **Open Your Eyes to the Skies: An Innovative and Interdisplinary Astronomy/Astrochemistry Teaching Laboratory**

Leslie Looney[1], B. McCall[1], N. Glumac[1]
[1]*University of Illinois.*
9:00 AM - 6:30 PM

At the University of Illinois, our historic observatory with a 12 inch Brashear refractor, has been transformed into a teaching facility that provides a hands-on astronomical experience for non-science and science major students. With the addition of new hardware, such as telescopes, CCDs, spectrometers, and a computer room, we have developed 1) an astrochemistry course with a high-resolution spectrometer for advanced science undergraduates and graduate students, 2) an independently accessed imaging and spectroscopy course for advanced science undergraduates, and finally 3) a TA led course with hands-on access to telescopes for non-science majors. In this poster, we present the details of the observatory transformation and the hardware.

437.06 – **The APSU 0.5m Telescope - A Hands-On Learning Environment for Secondary Teachers**

J. Allyn Smith[1], S. L. Buckner[1], S. F. Pirkle[1]
[1]*Austin Peay State Univ..*
9:00 AM - 6:30 PM

Physical science teachers with hands-on experience are critical to secondary education learning. In "Before It's Too Late," the U.S. Department of Education (2000) estimated "about 56% of high school students taking physical science are taught by out-of-field teachers." In Tennessee, the problem is even greater, while the demand is increasing. This project aims to address the shortage of well-prepared physics and astronomy teachers.

Austin Peay State University has recently installed a 0.5m telescope with imaging and rudimentary spectroscopic capability. We are committed to working with the College of Education to bring secondary teachers in training and practicing secondary teachers to the telescope to experience basic operations and conduct small research projects. This is done via classes and summer workshops. We describe the program setup, expectations for the participants, learning outcomes, and the evaluation process.

437.07 – **Teach Astronomy: An Online Textbook for Introductory Astronomy Courses and Resources for Informal Learners**

Kevin Hardegree-Ullman[1], C. D. Impey[1], A. Patikkal[1]
[1]*University of Arizona.*
9:00 AM - 6:30 PM

This year we implemented Teach Astronomy (www.teachastronomy.com) as a free online resource to be used as a teaching tool for non-science major astronomy courses and for a general audience interested in the subject. The comprehensive content includes: an introductory astronomy text book by Chris Impey, astronomy articles on Wikipedia, images from the Astronomy Picture of the Day, two to three minute topical video clips by Chris Impey, podcasts from 365 Days of Astronomy, and astronomy news from Science Daily. Teach Astronomy utilizes a novel technology to cluster, display, and navigate search results, called a Wikimap. Steep increases in textbook prices and the unique capabilities of emerging web technology motivated the development of this free online resource. Recent additions to Teach Astronomy include: images and diagrams for the textbook articles, mobile device implementation, and suggested homework assignments for instructors that utilize recent discoveries in astronomy. We present an overview of how Teach Astronomy has been implemented for use in the classroom and informal settings, and suggestions for utilizing the rich content and features of the web site.

437.08 – **Astr 101 Students' Attitudes Towards Essays On Transits, Eclipses And Occultations**

Noella L. D'Cruz[1]
[1]*Joliet Junior College.*
9:00 AM - 6:30 PM

Joliet Junior College, Joliet, IL offers a one semester introductory astronomy course each semester. We teach over 110 primarily non-science major students each semester. We use proven active learning strategies such lecture tutorials, think-pair-share questions and small group discussions to help these students develop and retain a good understanding of astrophysical concepts. Occasionally, we offer projects that allow students to explore course topics beyond the classroom. We hope that such projects will increase students' interest in astronomy. We also hope that these assignments will help students to improve their critical thinking and writing skills.

In Spring 12, we are offering three short individual essay assignments in our face-to-face sections. The essays focus on transits, eclipses and occultations to highlight the 2012 transit of Venus. For the first essay, students will find images of transit and occultation events using the Astronomy Picture of the Day website and describe their chosen events. In addition, students will predict how variations in certain physical and orbital parameters would alter their particular events. The second essay involves transits, eclipses and occultations observed by spacecraft. Students will describe their transit event, their spacecraft's mission, orbital path, how the orbital path was achieved, etc. The third essay deals with transiting exoplanets. Students will choose at least two exoplanets from an exoplanet database, one of which has been discovered through the transit method. This essay will enable students to learn about detecting exoplanets and how they compare with our solar system.

Details of the essay assignments and students' reactions to them will be presented at the meeting.

437.09 – **Introducing the 'Science Myths Revealed' Misconception Video Series**

Bonnie Eisenhamer[1], R. Villard[1], M. Estacion[1], J. Hassan[1], H. Ryer[1]
[1]*STScI.*
9:00 AM - 6:30 PM

A misconception is a preconceived and inaccurate view of how the world works. There are many common science misconceptions held by students and the public alike about various topics in astronomy - including but not limited to galaxies, black holes, light and color, and the solar system. It is critical to identify and address misconceptions because they can stand in the way of new learning and impeded one's ability to apply science principals meaningfully to everyday life. In response, the News and Education teams at the Space Telescope Science Institute worked in collaboration with a consultant to develop the "Science Myths Revealed"

misconception video series. The purpose of this video series is to present common astronomy misconceptions in a brief and visually engaging manner while also presenting and reinforcing the truth of the universe and celestial phenomena within it. Viewers can the watch the videos to get more information about specific astronomy misconceptions as well as the facts to dispel them. Visual cues and demonstrations provide viewers with a more concrete representation of what are often abstract and misunderstood concepts - making the videos ideal as both engagement and instructional tools. Three videos in the series have been produced and are currently being field-tested within the education community.

437.1 – **Gravitational Wave Astronomy in the High School Classroom**

Benjamin F. Farr[1], G. Schelbert[2], L. Trouille[1]
[1]*Northwestern University,* [2]*Evanston Township High School.*
9:00 AM - 6:30 PM

Gravitational wave astronomers are on the verge of being able to detect extreme cosmic events, like the merger of two black holes, happening hundreds of millions of light years away. Their work has the potential to propel astronomy into a new era by providing an entirely new means of observing astronomical phenomena. Gravitational wave astronomy encompasses astrophysics, physics, engineering, and quantum optics. As a result, a curriculum based on gravitational wave astronomy exposes students to the interdisciplinary nature of science. It also provides an authentic context for students to learn about astrophysical sources, data analysis techniques, cutting-edge detector technology, and error analysis. We present our efforts to create and implement a year-long high school astronomy curriculum with gravitational wave astronomy integrated into lessons throughout the year.

437.11 – **Big Explosions and Strong Gravity: A Framework for Astronomy Outreach at a University**

Sarah E. Eyermann[1], A. E. Hornschemeier[1]
[1]*NASA GSFC.*
9:00 AM - 6:30 PM

Big Explosions and Strong Gravity (BESG) is a curriculum that provides the framework for an event where students explore the science behind supernovae and black holes. The hands-on activities are tailored to students at the middle school level, and ideally are led by scientists, engineers, postdocs, and grad students in astronomy-related fields. In addition to providing the students with the best science knowledge possible, this direct connection with people who have chosen these areas as a career allows the students to reassess their ideas of who can go into these fields.

The activities within Big Explosions and Strong Gravity address the fascination middle school students have with the Universe that lies beyond the solar system - an area they typically do not study during the school day. During the course of a day, students explore the creation of elements in stars, the importance of supernovae in that process, the abundance and distribution of elements in the universe, how we identify those elements in distant stars, and how we detect black holes. The program is well-tested and evaluated, and has been reviewed by both subject matter and education experts through NASA's internal product review system.

The middle school years are a critical time in the development of attitudes about science and career options, especially in girls, so there is a need to engage students in science at this age. This program was originally developed for Girl Scout groups, but the activities are appropriate for a much broader audience than just Girl Scouts. We are currently seeking partners and expanding our available resources with the goal of broadening this program's reach. University science departments seeking a framework for a one-day outreach effort would be a natural partner, due to the importance of the scientist-student connection in this program.

437.12 – **New Planetarium Show: "Max Goes To The Moon"**

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

As part of our NASA Lunar Science Institute funding we have focused on making a children's planetarium show about space science and exploration. We decided to adapt an award winning children's book, "Max Goes to the Moon" by Dr. Jeffrey Bennett into a planetarium show. This story follows the adventure of a dog names Max and his friend/owner Tori. The two of them go on an amazing journey to the Moon and back. Not only is the show a great adventure but it also teaches many concepts pertaining to our current understanding of the Earth-Moon system. We based many of these concepts to fit the new State and Federal education standards.

437.13 – **Snapshots of the Universe: A Multi-Lingual Astronomy Art Book**

Rachael Beaton[1], L. Jackson[1], J. Carlberg[2], K. Johnson[1], R. Marchand[3], G. Sivakoff[3], I. Czekala[4], G. Damke[1], J. Dean[1], M. Drosback[5], N. Gugliucci[1], O. Martinez[4], A. Wong[1], G. Zasowski[1], Dark Skies, Bright Kids
[1]*Univ. of Virginia,* [2]*Carnegie DTM,* [3]*Univ. of Alberta, Canada,* [4]*Harvard/CfA,* [5]*AAAS/AIP Congressional Fellow.*
9:00 AM - 6:30 PM

Dark Skies, Bright Kids! (DSBK) is a dynamic education and public outreach organization at the University of Virginia, focused on enhancing elementary level science education in rural and underserved communities. DSBK thrives on the efforts of undergraduate, graduate and post-doctoral volunteers. Early in the program, our volunteers encountered difficulties connecting with "English as a second language" students. To meet that challenge, DSBK volunteers created art with short descriptions of astronomical objects in both Spanish and English to help communicate concepts across the language barrier. Building on this initial success, our simple art project has evolved into a full educational children's book targeted at 2nd - 5th grade students. Though originally in Spanish and English, a partnership with the University of Alberta (Canada) has produced a French translation of the text, broadening the outreach potential of the book. Here we present our 'Snapshots of the Universe' for broad distribution to classrooms, school libraries and homes, with emphasis on those serving multi-lingual populations, as a unique tool for introducing astronomy concepts at the elementary school level.

437.14 – **Training Families To Learn Science Together Using Astronomical Topics**

Jacob Noel-Storr[1], G. Wyllie[1], D. Lierheimer[1]
[1]*Rochester Inst. Of Technology.*
9:00 AM - 6:30 PM

We present a collection of messages and lessons learned from a set of Family Science programs that have been developed, implemented and/or evaluated by the RIT Insight Lab over the past 5 years. The programs are connected by their use of astronomical topics to serve as the motivator for engagement and learning. The programs all focus on the development of inquiry skills and connecting family members to each other as science learning communities, rather than focusing on the development of specific content knowledge. We show how family science programs can increase engagement in STEM for parents and their children alike, and strengthen the pipeline of the next generation of scientists and engineers.

437.15 – **The IRIS Mission: A Colorful EPO Program**

Deborah K. Scherrer[1]
[1]*Stanford Univ..*
9:00 AM - 6:30 PM

We will overview NASA's IRIS mission EPO program, which includes a nationwide spectroscopy contest, K-12 resources, a summer program for undergraduates, informal outreach elements, and a dynamic social media program based on the highly successful Camilla/Little SDO program for NASA's SDO mission.

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438 – Star Clusters

Poster Session – Exhibit Hall, Dena'ina Center – 6/13/2012 9:00:00 AM to 6/13/2012 7:30:00 PM

438.01 – **Cluster Membership, Binarity and Stellar Rotation in the Young Open Cluster M37**

Aaron M. Geller[1], S. Meibom[2], S. Barnes[3], R. D. Mathieu[4], J. Hartman[5], M. Holman[2]
[1]*Northwestern University,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*Space Science Institute,* [4]*University of Wisconsin - Madison,* [5]*Princeton University.*
9:00 AM - 6:30 PM

We present results from our comprehensive radial-velocity survey of the young open cluster M37 (NGC 2099; ~540 Myr). This ongoing survey began in 2007 and combines data from the MMT 6.5m telescope and the WIYN 3.5m telescope as part of the WIYN Open Cluster Study (WOCS). Our stellar sample covers all upper main-sequence stars down to 5.5 magnitudes below the turnoff ($11 < V < 18.5$; $2.8 < M\ [M_\odot] < 0.8$) and spans a 30' x 25' (11 x 13 pc; 4.8 x 5.7 core radii) region on the sky. To date we have observed 1717 stars, 895 of which have at least 3 radial-velocity measurements. Here we identify 545 single and binary cluster members, and present a color-magnitude diagram cleaned from field-star contamination. Importantly many of these stars also have rotation-period measurements, allowing for a comparison of the stellar rotation rates between the single and binary cluster members.

This work is funded by the National Science Foundation grant AST-0908082 to the University of Wisconsin - Madison, the Lindheimer Fellowship at Northwestern University, NASA grant NNX09AH18A to S.M., and by support to S.M. from the Kepler mission via NASA Cooperative Agreement NCC2-1390.

438.02 – **H-alpha and H-beta Photometry of Selected Open Clusters**

Michael D. Joner[1], E. G. Hintz[1]
[1]*Brigham Young Univ..*
9:00 AM - 6:30 PM

We present new data for the open clusters M35, M67, NGC 188, NGC 752, NGC 869, and NGC 884 secured at the Brigham Young University West Mountain Observatory using standard H-beta filters as well as standard filters for the recently defined BYU H-alpha photometric system. Aside from being well suited for surveys and studies of emmision line objects such as HMXBs and YSOs, the combination of these two reddening independent indices provides a reliable temperature measure for individual stars within a cluster with the H-alpha index reaching stars of slightly cooler temperature than can be found from H-beta measurements.

We acknowledge the Brigham Young University College of Physical and Mathematical Sciences for continued support of the research programs at the West Mountain Observatory. Partial supprot for this research was received through NSF grant AST #0618209.

438.03 – **A New Analysis of Multiple Main-Sequence Turn-Offs in**

Intermediate-Age Star Clusters

Vera Kozhurina-Platais[1], A. Dotter[1], S. E. de Mink[1], I. Platais[2], P. Goudfrooij[1]
[1]*STScI,* [2]*JHU.*
9:00 AM - 6:30 PM

A total of 21 intermediate-age LMC/SMC star clusters, observed with the HST/ACS/WFC, were selected from the HST Archive with the intention to provide a new insights into the complex nature of the multiple main-sequence turn-offs. Newly derived color-magnitude diagrams (CMDs) from high-precision ePSF fitting photometry, corrected for the Charge Transfer Inefficiency, provide a precise, homogeneous, and statistically superior sample that allows us to re-address the nature of multiple main-sequence turn-offs in these clusters. The approach for understanding the origin of the multiple main-sequence turn-offs are as follows: 1)determination of self-consistent and accurate ages through the fitting isochrones with new set of stellar models; 2)detailed analysis of CMDs and the multiple main-sequence turn-offs; 3)assess the differential reddening effect; 4)detailed consideration of the stellar astrophysics via two key physical processes: convective core overshoot and stellar rotation.

438.04 – **A High Resolution Spectroscopic Investigation of Near-Turnoff Stars in M67**

Courtney McGahee[1], J. R. King[1], C. P. Deliyannis[2], R. M. Maderak[2]
[1]*Clemson University,* [2]*Indiana University.*
9:00 AM - 6:30 PM

We describe a high-resolution spectroscopic survey of near-turnoff stars in the open cluster M67. Observations were conducted using the WIYN 3.5m telescope in conjunction with the HYDRA spectrograph at Kitt Peak National Observatory. We present preliminary results concerning two anomalous sub-groups of near-turnoff stars, blue stragglers and bright subgiants, which may lead to new insights into the evolution of such objects. Support for this was provided by NSF grant AST 09-08342.

438.05 – **Searching for Metallicity Spread in Star Clusters using HST/WFC3 Multiband Photometry**

Daniel Oravetz[1], J. Holtzman[1]
[1]*New Mexico State University.*
9:00 AM - 6:30 PM

We study the internal distribution of metallicities in stellar clusters using multiband HST/WFC3 images that include observations in filters designed to be more sensitive to metallicity than standard broadband filters. We analyze observations of NGC 104, NGC 6752, M92, NGC 5927, and NGC 6791, which span a range of metallicities, -2.2 < [Fe/H] < 0.2. We search for metallicity spread along both the main sequence and the red giant branch by comparing the observed width of the stellar loci in the hk index to the spread expected from photometric errors.

438.06 – **A New Explanation of Globular Cluster Color Bimodality: 6-year Results and Implications**

Suk-Jin Yoon[1]
[1]*Yonsei Univ., Korea, Republic of.*
9:00 AM - 6:30 PM

The colors of globular clusters (GCs) in most large early-type galaxies are bimodal. This is generally taken as evidence for the presence of two GC subpopulations with different geneses, and thus forms a critical backbone of various galaxy formation theories. However, Yoon et al. (2006, Science 311, 1129) showed that the metallicity-color relations are highly inflected due to two complementary effects: (i) the integrated color of main-sequence and giant-branch is a mild nonlinear function of metallicity, and (ii) the rapid change in color due to the onset of the hot horizontal-branch further strengthens the non-linearity. Such nonlinear nature creates ''bimodal'' color distributions of old GCs from a broad underlying metallicity spread, even if it is unimodal. In this contribution, we summarize the 6-year results of theoretical and observational studies on the ''nonlinear color-metallicity relation'' scenario for the GC color bimodality and its implications on galaxy formation theories. We show that the hypothesis gives remarkably simple and cohesive explanations for all the key observations, including the close link of the GC color distributions to the host galaxy properties and the curious discrepancy in metallicity distribution functions between GC systems and their host galaxies’ constituent stars.

438.07 – **The Structural Parameters of the Globular Clusters in M31 with PAndAS**

Kristin Woodley[1], The Pan-Andromeda Archaeological Survey (PAndAS)
[1]*University of British Columbia, Canada.*
9:00 AM - 6:30 PM

The Pan-Andromeda Archaeological Survey (PAndAS) has obtained images with the Canada France Hawaii Telescope using the instrument MegaCam, covering over 400 square degrees in the sky and extending beyond 150 kpc in radius from the center of M31. With this extensive data set, we have measured the structural parameters of all confirmed globular clusters in M31 as well as for a large fraction of the candidate globular clusters in the Revised Bologna Catalog V.4 (Galleti et al. 2004, A&A, 416, 917). In this paper, we present their parameters, including their core-, effective (half-light)-, and tidal radii, as well as their ellipticities measured in a homogeneous manner with ISHAPE (Larsen 1999, A&AS, 139, 393). We examine these parameters as functions of radial position, luminosity, color, metallicity, and age. We also use our measurements as an additional parameter to help constrain the candidacy of the unconfirmed globular clusters.

438.08 – **Characterizing Globular Clusters Using a Bayesian Approach**

Roger Cohen[1], T. von Hippel[2], A. Sarajedini[1]
[1]*Univ. Of Florida,* [2]*Embry-Riddle Aeronautical University.*
9:00 AM - 6:30 PM

We determine the parameters of Galactic globular clusters and compare Bayesian results to those obtained by traditional isochrone fitting methods using the same set of stellar models. We demonstrate the advantages of our Bayesian technique with regard to quantifying uncertainties, as well as yielding star-by-star information on mass, membership and binarity in a probabilistic sense. In addition, we discuss present and future applications of our approach, including large scale surveys and multiple stellar populations.

438.09 – **Stellar Debris Streams in the WISE All-Sky Data Release**

Carl J. Grillmair[1], R. Cutri[1], F. Masci[1], T. Jarrett[1]
[1]*Caltech.*
9:00 AM - 6:30 PM

We apply matched-filter techniques to point sources in the WISE All-Sky data release to search for evidence of nearby tidal debris streams. Finding many such streams will be important, both for measuring the Galaxy's global potential and for mapping the distribution of dark matter. Combining WISE and 2MASS photometry enables us to isolate stellar populations of a given age and metallicity, and to penetrate regions of higher extinction near the Galactic plane. Despite the relatively bright limiting magnitudes of the surveys, we find evidence for a number of nearby streams, ranging from 45 to over 180 degrees in length. Better characterizing these streams and their progenitors will be a major goal of several wide-field, spectroscopic surveys currently planned or in progress.

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439 – LAD Business Meeting

Town Hall – Summit Hall 1, Egan Center – 6/13/2012 12:45:00 PM to 6/13/2012 1:45:00 PM

The Steering Committee of the Laboratory Astrophysics Division (LAD)invites you to attend the inaugural LAD Business Meeting. We willdescribe the functioning of LAD during the start-up period and discussplans and activities for the future of the division. We also want tohear any suggestions that you may have for the LAD and answer anyquestions that people may have. Elections will be held after thistransition period in the near future and your voices need to be heard.The session will be collectively chaired by the LAD Steering Committee.

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500 – SPD Parker Lecture: Solar Twins and Stellar Maunder Minima

Invited Session – Ballroom B, Dena'ina Center – 6/14/2012 8:30:00 AM to 6/14/2012 9:20:00 AM

500.01 – **Solar Twins and Stellar Maunder Minima**

Jeffrey C. Hall[1]
[1]*Lowell Obs..*
8:30 AM - 9:20 AM

In 1966, Olin C. Wilson undertook an answer to the question “Does the chromospheric activity of main-sequence stars vary with time, and if so, how?”, initiating the so-called HK Project at Mount Wilson Observatory, which resulted in a magnificent 43-year data set and which has spawned a number of complementary synoptic programs in both hemispheres. Subsequent developments, in particular the realization that activity controls angular momentum evolution in the stars and Sun, that solar activity modulates irradiance, and that there was a pronounced response of terrestrial climate to the Maunder Minimum, spurred efforts to identify solar twins, stars that Giusa Cayrel de Strobel required to possess “fundamental physical parameters very similar, if not identical to those of the Sun.” Non-cycling states appear to occur in the Mount Wilson stars and in other synoptic data with about the same frequency that the Sun’s grand minima occur in the long-term proxy record, suggesting that stellar analogs of the Maunder Minimum may be used to guide understanding of the Sun’s state in the late seventeenth century and, as appears possible given the extended Cycle 23/24 minimum, in the near future. However, the magnitude limits of the existing surveys have kept the sample of solar twins small and long-term monitoring programs have only recently begun to accumulate good time-domain data beyond the canonical HK-index. Addressing these and other issues toward understanding prolonged stellar minima is therefore a key area of inquiry in solar-stellar connection work for the next decade. I will summarize the state of the field and the most promising lines of work for the immediate future. I and my colleagues Wes Lockwood and Brian Skiff sincerely appreciate the National Science Foundation’s long-time support of stellar cycles work at Lowell Observatory.

501 – Bridging Laboratory and Astrophysics: Nuclear

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying nuclear processes which drive our cosmos.

501.01 – **Nuclear Physics Input for Supernova Explosion and Nucleosynthesis**

Yong-Zhong Qian[1]

[1]*University of Minnesota.*

10:00 AM - 10:30 AM

All four fundamental interactions are involved in core-collapse supernovae. This talk reviews (1) the role of the equation of state for dense matter, (2) weak interaction processes associated with core collapse, explosion, and nucleosynthesis, (3) nuclear data for heavy element production, and (4) effects of neutrino oscillations. Laboratory experiments and astrophysical observations that can shed light on processes in core-collapse supernovae are discussed.

501.02 – **Nuclear and Computational Physics for Predictive Simulations of the S Process**

Falk Herwig[1]

[1]*University of Victoria, Canada.*

10:30 AM - 11:00 AM

The origin of the elements in stars and stellar explosion is a complex multi-physics, multi-scale problem that requires high-fidelity input from a diverse range of sub-disciplines, including nuclear physics as well as advanced computational techniques. I review briefly the state of our current modeling capabilities of the slow neutron capture process, that is responsible for the production of half of the trans-iron elements. I will quantitatively highlight some examples of how overall simulation predictions depend on uncertainties in underlying nuclear physics data as well as the accuracy of underlying simulation approaches. I will contrast the present simulation-based understanding of the physics of the s process with the observational picture based on astronomical observation and laboratory analysis of pre-solar grains.

501.03 – **Measuring Nuclear Reactions to Understand Astrophysical Processes**

Artemis Spyrou[1]

[1]*Michigan State University.*

11:00 AM - 11:30 AM

Major effort was devoted in the past decades for the understanding of the different nucleosynthesis processes. There are still, however, many open questions that need to be resolved. Often there are large uncertainties related to the modeling of these processes, which may come from uncertainties in the astrophysical description or from large uncertainties in the nuclear input used in these calculations. One of the puzzles of stellar nucleosynthesis is the production of the so called “p nuclei”. These rare nuclei are not produced by the two neutron induced (s- and r-) processes that can create the majority of the other nuclides beyond iron. It is still unclear what is the mechanism that creates these proton rich isotopes. The proposed scenarios (such as the “γ process” and the νp process) have to date not been successful in reproducing the abundance pattern. This talk will focus on outlining the nuclear uncertainties related to these nucleosynthesis processes with a focus on the experimental point of view: what can nuclear experimenters do to help with solving this puzzle?

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502 – Galaxy Mergers from the Largest to the Smallest Scales: Post-Merger Signatures and Recoiling SMBHs

Meeting-in-a-Meeting – Room 2, Dena'ina Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

The final black hole produced from the coalescence of SMBHS with unequal masses and/or spins can recoil at velocities exceeding 3000 km/s, due to the asymmetric emission of gravitational waves. In this session, we present the latest predictions for recoil velocities as calculated by numerical simulations. We then examine possible electromagnetic signatures of recoil, including its influence on any surrounding accretion disk. We conclude by examining astrophysical implications of recoil, with potential implications for galaxy evolution at the epoch of structure formation, as a new tracer of the merger history in clusters of galaxies, and effects on the nuclear structure of AGN. This session links back to the earlier sessions, re-emphasizing the various and tight links between different stages of galaxy mergers from large to small scales.

502.01 – **Numerical Relativity Calculations of Black Hole Recoils**

Manuela Campanelli[1]

[1]*Rochester Institute of Technology.*

10:00 AM - 10:20 AM

The field of numerical relativity experienced a phenomenal growth spurt during the past six years. The field transformed from one in which the two-body problem, that is the merger of black-hole binaries, was impossible to solve to one where simulations of merging black-holes are now routine. Among the most remarkable discoveries is the one that merging pair of spinning black holes can recoil thousands of km/s, generating very strong emission of gravitational waves in the last few orbits of the collision. The detection these gravitational waves will constitute a major breakthrough in fundamental physics, opening a new window on the universe. For supermassive black-holes in active galaxies, these merger events are also expected to be accompanied by observable electromagnetic signals. In this talk, I will review the latest achievements and highlight the field’s next challenges with emphasis on applications to gravitational wave recoils. I will also present the first magnetohydrodynamics (MHD) calculation of a circumbinary accretion disk around inspiralling supermassive black-holes.

502.02 – **Observational Signatures of Recoiling Supermassive Black Holes**

Andrew Robinson[1]

[1]*RIT.*

10:20 AM - 10:40 AM

Anisotropic emission of gravitational waves during the coalescence of a binary Supermassive Black Hole (SMBH) can impart a significant recoil velocity to the merged SMBH. Following recent advances in numerical relativity it has been shown that, for certain configurations of the original binary, recoil velocities up to several 1000 km/s are possible, leading to long-lived oscillations within the host galaxy or, in extreme cases, ejection of the SMBH from the galaxy. Such recoiling SMBH's might be detected observationally as off-center Active Galactic Nuclei, or via Doppler shifting of emission lines from the retained gas. In this contribution, we will review observational signatures of recoiling SMBH, outline some techniques that have been employed to search for these objects and review the properties of several interesting candidates that have been discovered to date.

502.03 – **Recoiling Massive Black Holes in Galaxy Mergers**

Piero Madau[1]

[1]*University of California, Santa Cruz.*

10:40 AM - 11:00 AM

The asymmetric emission of gravitational waves produced during the coalescence of a massive black hole (MBH) binary imparts a velocity "kick" to the system that can displace the hole from the center of its host. I will discuss the trajectories and observability of MBHs recoiling in gas-rich galaxy merger remnants using high-resolution hydrodynamical simulations.

502.04 – **Electromagnetic Emission from Supermassive Black Hole Mergers**

Zoltan Haiman[1]

[1]*Columbia University.*

11:00 AM - 11:20 AM

Any detectable EM emission arising from a coalescing SMBH binary is likely to be time-variable, which should aid in its identification. I will discuss three possibilities for such variable emission: (i) periodic signals due to the orbital motion prior to coalescence; and transient "after-glows" produceds by (ii) post-merger gas accretion and by (iii) merger-induced shocks in the circumbinary disk. These time-variable EM signatures may be used to identify unique counterparts of gravitational wave (GW) sources expected to be detected by (e)LISA and by Pulsar Timing Arrays. The variable/transient sources may also be identified in EM surveys without a GW trigger.

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503 – Lyman Alpha Emitters as Probes of Galaxy Formation and Cosmology: Measuring Large-Scale Structure

Meeting-in-a-Meeting – Summit Hall 2, Egan Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

Three 20+5 minute talks will be given summarizing the extent to which Lyman Alpha Emitters (LAEs) can be used as reliable tracers of the dark matter distribution. Large surveys of LAEs plan to use their spatial clustering to probe the properties of dark energy and dark matter. This requires a deep understanding of the correspondence between observed LAEs and the underlying dark matter halos. The requirement for significant Lyman Alpha emission to escape a galaxy for it to enter a sample of LAEs makes radiative transfer a key ingredient in developing this understanding, and radiative transfer effects on both local and cosmological scales will be described. Furthermore, the study of rare overdense regions in large Ly alpha surveys gives

clues to the formation of galaxy clusters and brightest cluster galaxies.The session will conclude with a 15-minute moderated discussion of outstanding questions and how to resolve them.

503.01 – **Large-Scale Structure of Lyman-Alpha Emitters from Radiative Transfer Modeling**

Zheng Zheng[1], R. Cen[2], H. Trac[3], J. Miralda-Escude[4]

[1]*University of Utah,* [2]*Princeton University,* [3]*Carnegie Mellon University,* [4]*Institucio Catalana de Recerca i Estudis Avancats, Spain.*

10:00 AM - 10:25 AM

The large-scale structure of galaxies in the universe has become a powerful probe of galaxy formation and cosmology. For Lyman-alpha emitters (LAEs), galaxies mainly selected from their Lyman-alpha emission, resonant scattering of Lyman-alpha photons can add a new ingredient in determining their spatial clustering. I will present a theoretical investigation of the clustering of LAEs from radiative transfer modeling performed in a reionization simulation of cosmological volume. The study reveals a coupling between the observed Lyman-alpha emission and the circumgalactic and intergalactic environments induced by the resonant scattering of Lyman-alpha photons. I will show how such an environment-dependent radiative transfer effect gives rise to new features in the clustering of LAEs. Finally, I will discuss the challenges and opportunities in using the clustering of LAEs to study structure formation and cosmology.

503.02 – **How Lyman Alpha Scattering Through Small-Scale Outflows Affects the Large Scale Clustering of Lyman Alpha Selected Galaxies**

Mark Dijkstra[1], S. Wyithe[2], R. Angulo[1]

[1]*Max Planck Institute for Astrophysics, Germany,* [2]*University of Melbourne, Australia.*

10:25 AM - 10:50 AM

Galaxies trace the underlying matter density field of our Universe, and hence, their large scale clustering contains a wealth of cosmological information. The Hobby-Eberly Dark Energy Experiment (HETDEX) aims to measure the large-scale clustering of Lyman alpha selected galaxies to specifically probe the properties of dark energy at redshifts between 2 and 4. The large-scale clustering of Lyman alpha selected galaxies has recently been shown to be affected by radiative transfer in the intergalactic medium, which thus provides a systematic uncertainty which is absent from is traditional galaxy surveys. This `non-gravitational' contribution to the large scale clustering of Lyman alpha selected galaxies depends strongly on lyman alpha luminosity in the exponential tail of the Lyman alpha luminosity function, and on the Lya spectral line shape as it emerges from LAEs. In particular, scattering through `small-scale' outflows can affect the Lya spectral line shape such that it strongly reduces most non-gravitational contributions to the clustering. The importance of intergalactic radiative transfer can likely be constrained by the HETDEX data itself, and the large-scale clustering of Lyman alpha selected galaxies indirectly constrains galactic outflows on interstellar scales.

503.03 – **The First Galaxy Clusters**

Roderik Overzier[1]

[1]*University of Texas at Austin.*

10:50 AM - 11:15 AM

Overdensities of galaxies found at z=2-6 can be used to study the progenitors of present-day massive galaxy groups and clusters. I will discuss the results of our statistical survey that combines (1) galaxies in high redshift overdensities, (2) galaxies in massive clusters at z<1.5 and (3) cosmological simulations to show how the formation of the Cluster Red Sequence, Brightest Cluster Galaxies and the Intra Cluster Light can be traced back to small overdensities in the large-scale galaxy distribution at high redshift. One of the surprises of this study is that none of the proto-clusters found in the literature to date appear to be capable of evolving into the most massive X-ray luminous clusters found at z~1. This suggests that the most spectacular cluster progenitors remain to be discovered. I will discuss the prospects for finding such objects using, e.g, the HETDEX survey, and assess the status of our study into the early days of galaxy cluster evolution.

504 – Einstein vs Schwinger: Who is Right about Gravity? III

Meeting-in-a-Meeting – Summit Hall 4, Egan Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

For some time General Relativity, the Standard Model of Cosmology, and the Standard Model of Particle Physics have been mutually supportive. Particle physicists have always known that their model is incomplete; something else is needed â€“ perhaps the Higgs Boson and related supersymmetric particles. Early results from the Large Hadron Collider have not yet identified physics beyond the Standard Model. A hoped-for candidate for dark matter, the lightest supersymmetric particle has yet to be observed.

In the fall of 2011, a new challenge to Einstein appeared: a tachyonic neutrino tunneling from CERN to Gran Sasso. This challenge sharpens an earlier result from MINOS which has a baseline from Fermilab to a mine in northern Minnesota. New results are expected by Spring, 2012. This session will explore evidence for New Physics and New Astronomy. The latter includes the Dark Ages and the peaks in the Cosmic Microwave Background observed by the Wilkinson Microwave Anisotropy Probe and the South Pole Telescope.

Speakers: John Cumalat, Gerrit Verschuur, and Gary Hinshaw

504.01 – **A View From a Particle Experimentalist**

John Perry Cumalat[1], D. F. Bartlett[1]

[1]*University of Colorado, Boulder.*

10:00 AM - 10:30 AM

The experimental community in astronomy and particle physics is engaged in a variety of searches for dark matter candidates. Thus far, no direct observational evidence of dark matter exists and a vast amount is required for astronomical observations of galaxies and galaxy clusters. Clearly, this is a problem. While the searches will (and should) continue, alternative gravity laws need to be considered, tested, and compared with observational data. The Cosinusoidal Potential is a striking potential where gravity behaves according to Newton at length scales less than 100pc, but has completely different behavior at longer length scales. While MOND has difficulty in explaining the Bullet Cluster, the Cosinusoidal Potential does not. This talk will provide an update from CERN on searches for new particles, but it will also address tests that have been made and need to be made using the Cosinusoidal Potential.

504.02 – **The Relationship Between WMAP (ILC) Small-scale Features and Nearby Galactic HI Structure**

Gerrit L. Verschuur[1]

[1]*University of Memphis.*

10:30 AM - 11:00 AM

Free-free emission from electrons in the interstellar medium is capable of producing high-frequency radiation at the level found in the small-scale structure observed by WMAP as revealed in the ILC data. In a limited area of sky several hundred close associations between the high-frequency continuum sources and HI features have been found and some of the most interesting ones will be illustrated. It requires only a fractional ionization of 5 - 10% of associated HI features to produce the observed small-scale structure in the continuum. New analysis shows that in several cases such emission is produced where filaments of HI are clearly interacting. Overall, the data strongly suggest that the bulk of the small-scale structure found in the ILC compilation of the WMAP data originates in the nearby interstellar medium. This has serious consequences for the cosmological interpretation of the data.

504.03 – **The Cosmic Microwave Background Radiation - A Unique Window on the Early Universe**

Gary Hinshaw[1]

[1]*University of British Columbia.*

11:00 AM - 11:30 AM

The cosmic microwave background radiation is the remnant heat from the Big Bang. It provides us with a unique probe of conditions in the early universe, long before any organized structures had yet formed. The anisotropy in the radiation's brightness yields important clues about primordial structure and additionally provides a wealth of information about the physics of the early universe. Within the framework of inflationary dark matter models, observations of the anisotropy on sub-degree angular scales reveals the signatures of acoustic oscillations of the photon-baryon fluid at a redshift of ~1100.

Data from the Wilkinson Microwave Anisotropy Probe (WMAP) satellite provide detailed full-sky maps of the cosmic microwave background temperature and polarization anisotropy. Together, the data provide a wealth of cosmological information, including the age of the universe, the epoch when the first stars formed, and the overall composition of baryonic matter, dark matter, and dark energy. The results also provide constraints on the period of inflationary expansion in the very first moments of time.

505 – Solar Systems II

Oral Session – Ballroom C, Dena'ina Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

505.01 – **A New Spitzer IRAC Technique to Characterize Exoplanet Atmospheres**

Jessica Krick[1], J. Ingalls[1], S. Carey[1], K. von Braun[1]

[1]*Caltech.*

10:00 AM - 10:10 AM

Spitzer's extended warm mission gives us the opportunity to contribute to its legacy by performing comparative science on atmospheres of extrasolar planets. Observation of phase curves produce maps of the longitudinal brightness/temperature distributions in the planetary atmospheres, which are then

used to calculate energy redistribution efficiencies between the hot dayside and cooler nightside − exoplanetary weather. Recent improvements in the calibration of IRAC make possible a new observing technique which will be much more efficient than standard staring mode observations by using snapshot observations to emulate a full phase curve. The challenge with using snapshot observations is in making sure all observing epochs can be tied together with high enough photometric precision. The dominant source of error in this task is intrapixel gain variations on sub pixel levels. We have effectively removed this source of error by using the Pointing Calibration and Reference Sensor (PCRS) onboard Spitzer for pointing repeatability that is significantly better than random pointing. Because we have achieved this excellent repeatability, we are able to build up a map of the intrapixel gain, which is then used to independently correct IRAC photometry as a function of position on the pixel. We discuss additional sources of noise below the gain variations, at the sub percent level, such as pixel-wise nonlinearities, and our efforts to remove them. We present preliminary 4.5 micron data of HD209458 where we compare staring mode observations to snapshots taken with this new technique, corrected by the gain and residual nonlinearity map, and comment on the scientific implications of the resultant phase curve.

505.02 – **Exploring the Smallest Planet Candidates from Kepler**

Thomas Barclay[1], J. Rowe[1], Kepler Science Team

[1]*NASA Ames Research Center.*

10:10 AM - 10:20 AM

Amongst the 2321 viable planet candidates found by the Kepler Mission to date are a handful of candidates which are Mars-sized and smaller. We have investigate this populations and identify those which are least likely to be the result of a false positive detection. While the majority of these have orbital periods of <3 days, a few appear to be more than just molten rocks. We have investigated methods with which to validate these smallest known candidates as bone fide planets and report this work.

505.03 – **A Non-detection Of Star-Planet Interaction In The Extreme Wasp-18 System**

Brendan P. Miller[1], E. Gallo[1], J. T. Wright[2], A. K. Dupree[3]

[1]*University of Michigan,* [2]*Pennsylvania State University,* [3]*Harvard-Smithsonian Center for Astrophysics.*

10:20 AM - 10:30 AM

We report recent observations of the extreme WASP-18 system, which features a massive close-in transiting planet (Mp = 10.1 Mjup, P = 0.94 d) orbiting a young F6 star. WASP-18 was targeted as an ideal testbed for investigating potential magnetic (or tidal) interactions between "hot Jupiters" and their host stars. The high-resolution echelle spectrograph MIKE was used on the 6.5m Magellan Clay telescope to obtain 13 spectra spanning planetary orbital phases of 0.7-0.4, while the X-ray Telescope on Swift provided contemporaneous monitoring with a stacked exposure of ~50 ks. We find that the cores of the Ca II H and K lines do not show significant variability over ~8 d, in contrast to the expectation of phase-dependent chromospheric activity enhancements for efficient star-planet interaction. The star is also X-ray faint, with log Lx < 27.5, indicating that coronal activity is likewise low. Consequently, any observable star-planet interaction in this extreme system must be at best highly transient. We additionally comment on general observational challenges to establishing robust detections of star-planet interaction. Our results suggest that the immediate utility of star-planet interaction to estimate exoplanet magnetic field strengths may be limited.

505.05 – **The FINESSE Mission**

Mark R. Swain[1]

[1]*JPL.*

10:40 AM - 10:50 AM

FINESSE, the Fast Infrared Exoplanet Spectroscopy Survey Explorer, is purpose-built for characterizing exoplanet atmospheres. Building on the extraordinary legacy of exoplanet discovery, FINESSE takes the next step to determine what exoplanet atmospheres are made of, what conditions or processes are responsible for the composition, and how our own solar system fits into the larger family of planets. During a two-year mission, FINESSE will survey 200 transiting exoplanets ranging from the most extreme hot-Jovians to cool Neptunes and Super-Earths. The FINESSE spectrometer, covering 0.7-5.0 microns, provides excellent sensitivity to important molecular bands of water, methane, carbon monoxide, carbon dioxide, and other molecules. Interpretation of FINESSE measurements will reveal the composition, temperature structure, and chemistry of exoplanet atmospheres and provides a basis for comparing exoplanets in a uniform way. Highly optimized for stability, FINESSE will determine the differences between the dayside and nightside of exoplanet atmospheres by precision measurements of the system phase curve. The FINESSE mission will also have a participating science program to observe targets outside the science baseline.

505.06 – **Exoplanets, Cool Stars, and Interferometry**

Kaspar von Braun[1], T. S. Boyajian[2], S. R. Kane[1], G. T. van Belle[3], L. Hebb[4], J. Jones[2], D. R. Ciardi[1], S. Raymond[5], M. Lopez-Morales[6], H. A. Knutson[1], T. ten Brummelaar[7], C. Farrington[7], G. Schaefer[7], T. CHARA Group[7]

[1]*Caltech,* [2]*Georgia State University,* [3]*Lowell Observatory,* [4]*Vanderbilt University,* [5]*Universite de Bordeaux, France,* [6]*Institut de Ciencies de L'Espai, Spain,* [7]*CHARA.*

10:50 AM - 11:00 AM

We have been using the CHARA Interferometric Array on Mount Wilson over the course of the last 4 years to directly determine diameters of stars. When coupled with literature photometry, these radii provide stellar effective temperatures, luminosities, and thus habitable zone locations. This presentation reviews recent results of our survey, particularly with respect to the stars that host extrasolar planets around them, and what we have learned about the planets from studying the parent stars.

505.07 – **The Effect of Planets Beyond the Ice Line on the Accretion of Volatiles by Habitable-Zone Rocky Planets**

Jack J. Lissauer[1], E. V. Quintana[1]

[1]*NASA Ames Research Center.*

11:00 AM - 11:10 AM

By cosmic standards, Earth is highly deficient in volatiles. The condensed component of a solar composition mixture that is cool enough for all of the water to be in solid form is over 50% ice by mass. In contrast, the Earth's oceans and other near-surface reservoirs represent only 0.03% of our planet's mass, with a comparable amount of water thought to lie in the mantle. So Earth was very inefficient in accreting water from the protoplanetary disk. To investigate how the type of star and giant planet configurations can affect the ability of Earth-size planets to accumulate and retain volatiles, we numerically model the late stages of terrestrial planet growth. We follow the evolution of numerous disks of planetesimals and embryos around a Sun-like star, and compare the effects of various giant planet or stellar companions on the accretion process. Our approach employs moderate-resolution simulations that have sufficiently modest computational requirements to allow us to perform the dozens of simulations required to disentangle effects of the companion body from stochastic variations that are an important aspect of terrestrial planet growth.

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506 – Stars with Disks, Pre-Main Sequence and Main-Sequence Stars

Oral Session – Room 1, Dena'ina Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

506.01 – **Dust and Gas Depletion in the Disk around Herbig Ae Star Oph IRS 48**

Joanna Brown[1], G. Herczeg[2], S. Andrews[1], E. van Dishoeck[3], D. Wilner[1], K. Rosenfeld[1], K. Pontoppidan[4]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Kavli Institute for Astronomy and Astrophysics, China,* [3]*Leiden Observatory, Netherlands,* [4]*Space Telescope Science Institute.*

10:00 AM - 10:10 AM

The processes that form transition disks - disks with depleted inner regions - are not well understood although possible scenarios include planet formation, grain growth and photoevaporation. Disks with well characterized dust holes are rare but even less is known about the corresponding gas structure, which should be diagnostic of the underlying physics. We present new resolved gas and dust observations of the Herbig Ae star Oph IRS 48. An extremely large 30 AU radius gas hole is seen directly in our VLT CRIRES observations of the fundamental band of CO at 4.7 micron. A hole of similar size was also previosuly detected in warm dust at 20 microns. However, PAH molecules, usually a gas tracer, are located within the hole. Our new high spatial resolution SMA imaging (0.3'') unexpectedly reveals a smaller hole in the millimeter dust grains. We will discuss the implications of this complex disk structure and the potential formation scenarios.

506.02 – **Model Images of Inclined Disks with Active Planet Formation**

Hannah Jang-Condell[1], N. J. Turner[2]

[1]*University of Wyoming,* [2]*JPL/Caltech.*

10:10 AM - 10:20 AM

Sub-Jupiter mass planets are capable of opening partial gaps in young protoplanetary disks. The size and depth of these gaps correlated with the planet mass and position, so the detection of a gap can constrain the characterics of a planet embedded in a disk, even though the planet itself may be obscured by disk material. We present model images of disks with gaps opened by planets, and demonstrate how the disk image changes with the inclination of the disk. We show model images in both total intensity and polarized scattered light. Both the thickness and inclination of the disk may be determined from asymmetries in the image. Polarized intensity imaging is a promising method of producing high contrast imaging, and can resolve the near side/far side degeneracy in the orientation of a disk. However, inferring the presence of planet can be difficult because of features introduced by varying fractional polarization across the disk surface.

506.03 – **An Eccentric Debris Ring around the Nearby G Star HD 202628**

Karl R. Stapelfeldt[1], J. E. Krist[2], G. C. Bryden[2], P. Plavchan[3]

[1]*NASA Goddard Space Flight Center,* [2]*Jet Propulsion Laboratory, Caltech,* [3]*NASA Exoplanet Science Institute.*

10:30 AM - 10:40 AM

A new debris disk has been imaged in visible light around the G2V star HD 202628 using the STIS coronagraph on the Hubble Space Telescope. The broad ring is inclined 61 deg from face-on and extends as far as 260 AU from the star. The star is noticeably displaced from the apparent ring center by 20 AU. The ring inner edge is sharp and well-described by an inclined ellipse with a= 158 AU, e= 0.18, and the star at one focus. These properties are similar to the Fomalhaut debris ring and likewise suggest ring sculpting by a planetary-mass companion with

semi-major axis ~> 100 AU. The presence of a planet so widely separated from a solar-type star poses a new challenge for planet formation theories.

506.04 – **Constraining Stellar Models With Extremely High-Precision Interferometric Measurements**

Anders M. Jorgensen[1], J. T. Armstrong[2], H. R. Schmitt[3], T. Hall[1], E. K. Baines[2], D. Mozurkewich[4], D. J. Hutter[5]

[1]*New Mexico Tech,* [2]*Naval Research Laboratory,* [3]*Computational Physics, Inc.,* [4]*Seabrook Enginering,* [5]*Naval Observatory Flagstaff Station.*
10:40 AM - 10:50 AM

When using traditional squared visibilities in optical interferometry very long integrations are required to obtain good signal-to-noise ratio on small visibilities, to the point where it becomes nearly impossible to measure very small visibilities. With phase-referencing and coherent integration the signal-to-noise ratio can be greatly improved. This in turn makes it possible to explore the behavior of the visibility close to the visibility nulls. This is important because the behavior of the visibility near nulls is more sensitive to stellar structure. In particular the location of the null can be determined with great precision, and used as a very high precision measure of the stellar diameter. We have demonstrated that this diameter measure can be obtained to a precision of better than 1:500 with the Navy Optical Interferometer. As the star transits across the sky the variation of projected baseline length causes the null to vary

in wavelength as well. This makes it possible to obtain the diameter of the star with very high precision as a function of wavelength. These high precision measurements should allow for

significant constraints on stellar models. In this presentation we explain the process of coherent integration, present measurements of stellar diameters as a function of wavelength, and compare these with some stellar models.

506.05 – **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 Neon fine structure emission from our sample and discuss the implications of these detections on disk evolution.

506.06 – **Radio Emission from YSOs : Tackling the (Reverse) Luminosity Problem**

Anna Scaife[1]

[1]*University of Southampton, United Kingdom.*
11:00 AM - 11:10 AM

The ‘classic luminosity problem’ has been known for some time, where the minimum accretion luminosities produced by the standard spherical collapse model are up to several orders of Magnitude larger than those observed for embedded protostars. The solution to this problem has been proposed as non-steady or episodic accretion rate onto such objects, and recent radiative transfer simulations have demonstrated that a combination of these effects can indeed reproduce the observed luminosity distribution. However, this work has also predicted a ‘reverse luminosity problem’, whereby an overabundance of objects is expected at very low luminosities relative to those observed. Although this effect is currently ascribed to observational completeness issues, further accurate comparison will not be possible without directed observational studies. Unfortunately, such low luminosity sources are difficult to identify in the infra-red as they are typically heavily embedded in thick dust cores, and the molecular emission from their outflows is frequently so weak that it is not easily or consistently detected. Radio emission from these objects provides a reliable alternative method for detection, as the dense dust cores are optically thin to the longer wavelength emission. I will present results from a number of recent radio surveys specifically targeted at low and very low luminosity objects and discuss the new physical insights into star formation processes which can be drawn from these data.

506.07 – **Gravitational Slingshot of Young Massive Stars in Orion**

Jonathan Tan[1], S. Chatterjee[1]

[1]*Univ. of Florida.*
11:10 AM - 11:20 AM

The Orion Nebula Cluster (ONC) is the nearest region of massive star formation and thus a crucial testing ground for theoretical models. Of particular interest amongst the ONC's ~1000 members are: theta1C, the most massive binary in the cluster with stars of masses 38 and 9 Msun; the Becklin-Neugebauer (BN) object, a 30 km/s runaway star of ~8 Msun; and the Kleinmann-Low (KL) nebula protostar, a highly-obscured, ~15 Msun object still accreting gas while also driving a powerful, apparently "explosive" outflow. The unusual behavior of BN and KL is much debated: How did BN acquire its high velocity? How is this related to massive star formation in the KL nebula? Here we report the results of a systematic survey using ~10^7 numerical experiments of gravitational interactions of the theta1C and BN stars. We show that dynamical ejection of BN from this triple system at its observed velocity leaves behind a binary with total energy and eccentricity matching those observed for theta1C. Several other observed properties of theta1C are also consistent with it having ejected BN and altogether we estimate there is only a ~10^-5 probability that theta1C has these properties by chance. Our results suggest that after being launched from theta1C 4,500 years ago, BN has plowed through the KL massive-star-forming core within the last 1,000 years causing its recently-enhanced accretion and outflow activity.

507 – Galaxy Clusters I

Oral Session – Ballroom A, Dena'ina Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

507.01 – **WITHDRAWN: Intrinsic and Observed Concentration-mass 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.*
10:00 AM - 10:10 AM

The concentration-mass relation represents a valuable tool to constrain cosmological parameters such as matter density and sigma_8. In the last few years, samples of optical and X-ray data led to the conclusion that the observed relation has a higher normalization and slope than predicted by dark-matter only simulations.

In this work, we explore whether this disagreement is real and, if so, why it exists. To this purpose, we consider 30 clusters simulated by progressively increasing the simulation complexity: (i) dark-matter only, (ii) non-radiative hydrodynamics, (iii) adding cooling, star-formation and feedback by Supernovae, (iv) further adding feedback by AGN. We produced X-ray and optical synthetic catalogues to derive the concentration-mass relation following an observational approach.

We find that even if cooling has the effect of steepening the concentration-mass relation with respect to the DM-only simulations, the introduction of AGN makes this difference small (5-10%). A larger variation is expected when reducing the radial range over which density profiles are fitted to a NFW profile. In particular if the external radius is about half R_{500} the slope can double its value.

Therefore, observations, suffering from background contamination, are more inclined to detect a steeper c-M relations. Finally, the strong lensing analysis of the synthetic catalogues shows a bias leading to an over-estimate the concentration of small objects.

We acknowledge financial contribution from contracts ASI-INAF I/023/05/0, ASI-INAF I/088/06/0, PRIN-INAF-2009 Grant "Towards an Italian Network for Computational Cosmology", INFN PD51, the Michigan Society of Fellow, and the Michigan Center for Theoretical Physics.

507.02 – **Joint SZ/X-Ray Deprojections and Nonthermal Pressure Profiles of Galaxy Clusters Using Bolocam**

Jennifer Shitanishi[1], E. Pierpaoli[1], S. Ameglio[1], J. Sayers[2], S. Golwala[2], N. Czakon[2], A. Mantz[3], K. Umetsu[4], E. Medezinski[5], M. Nonino[6], A. Molino[7], M. Postman[8]

[1]*University of Southern California,* [2]*California Institute of Technology,* [3]*NASA Goddard Space Flight Center,* [4]*Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan,* [5]*John Hopkins University,* [6]*INAF Osservatorio Astronomico di Trieste, Italy,* [7]*Instituto de Astrofísica de Andalucía (CSIC), Spain,* [8]*Space Telescope Science Institute.*
10:10 AM - 10:20 AM

The properties of the intracluster medium (ICM) at large radii are not completely known. Characterizing these regions will provide a better understanding of cluster physics, and therefore tighter constraints on cosmological parameters. The Sunyaev-Zel’dovich (SZ) effect - the inverse Compton scattering of CMB photons with higher energy electrons in galaxy clusters - provides a redshift-independent means of measuring ICM properties. Bolocam is a millimeter-wave imaging camera that operates from the Caltech Submillimeter Observatory (CSO) with an 8 arcminute field of view used to detect the SZ effect. Greater than 40 massive galaxy clusters were detected at arcminute resolution with redshifts 0.15<z<0.89. All clusters in our sample have archival Chandra X-ray data and several have multi-band strong and weak lensing data from HST and Subaru. The results of two efforts to combine the data will be presented. First: the gas density and temperature profiles beyond r500 are obtained from a joint SZ/X-ray deprojection method using thermal SZ and X-ray surface brightness maps. This analysis models clusters with an onion-like structure and assumes spherical symmetry. A single joint likelihood function is maximized by fitting the two signals through a Monte Carlo Markov Chain (MCMC) approach. Second: the nonthermal pressure component is determined out to the virial radius, obtained from a combined SZ/X-ray/lensing analysis. The total pressure is estimated assuming hydrostatic equilibrium, with the lensing data providing the enclosed mass, and the X-ray the gas density, while the thermal pressure is derived directly from the SZ. Thermal to total pressure ratios are found, allowing insight into the nonthermal component.

507.03 – **Calculating Cluster Masses via the Sunyaev-Zel'dovich Effect**

Ashley Lindley[1], D. Landry[1], M. Bonamente[1], M. Joy[2], E. Bulbul[3], J. E. Carlstrom[4], T. L. Culverhouse[4], M. Gralla[4], C. Greer[4], D. Hawkins[5], J. W. Lamb[5], E. M. Leitch[5], D. P. Marrone[6], A. Miller[7], T. Mroczkowski[8], S. Muchovej[5], T. Plagge[4], D. Woody[5]

[1]*University of Alabama Huntsville,* [2]*NASA Marshall Space Flight Center,* [3]*Harvard - Smithsonian Center for Astrophysics,* [4]*University of Chicago,* [5]*Owens Valley Radio Observatory,* [6]*University of Arizona,* [7]*Columbia University,* [8]*Jet Propulsion Laboratory/California Institute of Technology.*
10:20 AM - 10:30 AM

Accurate measurements of the total mass of galaxy clusters are key for measuring the cluster mass function and therefore investigating the evolution of the universe. We apply two new methods to measure cluster masses for five galaxy clusters contained within the Brightest Cluster Sample (BCS), an X-ray luminous statistically complete sample of 35 clusters at z=0.15-0.30. These methods distinctively use only observations of the Sunyaev-Zel'dovich (SZ) effect, for which the brightness is redshift independent. At the low redshifts of the BCS, X-ray observations can easily be used to determine cluster masses, providing convenient calibrators for our SZ mass calculations. These clusters have been observed with the Sunyaev-Zel'dovich Array (SZA), an interferometer that is part of the Combined Array for Research in Millimeter-wave Astronomy (CARMA) that has been optimized for accurate measurement of the SZ effect in clusters of galaxies at 30 GHz. One method implements a scaling relation that relates the integrated pressure, Y, as determined by the SZ observations to the mass of the cluster calculated via optical weak lensing. The second method makes use of the Virial theorem to determine the mass given the integrated pressure of the cluster. We find that masses calculated utilizing these methods within a radius r500 are consistent with X-ray masses, calculated by manipulating the surface brightness and temperature data within the same radius, thus concluding that these are viable methods for the determination of cluster masses via the SZ effect. We present preliminary results of our analysis for five galaxy clusters.

507.05 – **Planck Intermediate Paper: Physics Of The Hot Gas In The Coma Cluster**

Pasquale Mazzotta[1], Planck Collaboration
[1]*CfA.*
10:50 AM - 11:00 AM

We present the data analysis of the Coma Cluster observed via Sunyaev-Zeldovich effect with the Planck satellite.

Being a low redshift massive hot clusters, its angular size is so extended that Planck can resolve it spatially. Thanks to its great sensitivity, Planck is capable, for the first time, to detect SZ emission up to r 3-4 t R500. This allow us to study the pressure distribution of the Intracluster Medium to the outermost cluster regions, not yet achieved by any other instrument. We test the validity of some pressure models proposed to described the pressure distribution in clusters. In particular we find that the Arnuad et al. pressure profile for merging systems provides a good fit of the data only at r<R500: at larger radii it seems to underestimate the observed profile up to 20%. This may either indicate that at these larger radii i) the cluster profile is contaminated by unresolved SZ sources along the line of sight ii) the pressure profile of Coma is higher than the mean pressure profile predicted by simulations. Very interestingly the Planck image shows two abrupt variations of the y signal located at approx 33 arcmin to the west and to the south east with respect to the cluster center. Using Planck y profiles extracted from corresponding sectors we verified that both abrupt variations are compatible with the presence of discontinuities of in the underlying density profile and we find pressure jumps of 4.5 and 4.9 in the west and south east, respectively.

Finally, we find that the y and radio-synchrotron signals are quasi-linearly correlated on Mpc-scales with very small intrinsic scatter. This implies either that the energy density of cosmic-ray electrons is relatively constant throughout the cluster, or that the magnetic fields fall off much slower with radius than previously thought.

507.06 – **The Effects Of AGN On X-ray And SZ Galaxy Clusters**

Camille Avestruz[1], D. Rudd[1], D. Nagai[1]
[1]*Yale University.*
11:00 AM - 11:10 AM

We present a sample of 16 simulated galaxy clusters generated with the Adaptive Refinement Treecode (ART), which, for the first time, include a prescription for the self-consistent growth of and feedback from supermassive black holes. We explore the coevolution of the cluster central galaxy, its associated supermassive black hole, and the intracluster medium at small scales. In particular, we discuss the impact of feedback on the well known over-cooling problem in numerical simulations, and the importance of this regulation on Sunyaev-Zeldovich and X-ray observations of clusters in the local universe.

507.07 – **A Comparison Of X-ray, Radio, And Lensing Results With GBT+MUSTANG Observations Of The Sunyaev-Zel'dovich Effect In Galaxy Clusters**

Tony Mroczkowski[1], M. Devlin[2], S. Dicker[2], P. Korngut[1], B. Mason[3], E. Reese[2], C. Romero[4], C. Sarazin[4], M. Sun[4], A. Young[2], Cluster Lensing And Supernova survey with Hubble
[1]*Jet Propulsion Lab / Caltech,* [2]*University of Pennsylvania,* [3]*NRAO,* [4]*University of Virginia.*
11:10 AM - 11:20 AM

We present recent high angular resolution (9") Sunyaev-Zel'dovich effect (SZE) observations with MUSTANG, a 90-GHz bolometric receiver on the 100-meter Green Bank Telescope (GBT). MUSTANG is now imaging a sample of clusters with complementary Chandra X-ray observations, HST optical observations that probe the mass distribution through strong and weak lensing, radio observations that probe the non-thermal component of the intra-cluster gas, and lower resolution SZE observations that can recover larger scales (>1'). The MUSTANG observations, which will be used to assess the impact of substructure on SZE scaling relations, are some of the highest resolution SZE images to date, and are revealing complex pressure substructures in intermediate redshift clusters. Combined, these observations reveal complicated cluster dynamics, which must be understood in order to use clusters as cosmological probes.

507.08 – **Search for Galaxy-ICM Interaction in Rich Cluster of Galaxies**

Liyi Gu[1], N. Inada[2], S. Konami[3], T. Kodama[4], K. Nakazawa[1], M. Kawaharada[5], K. Makishima[1]
[1]*University of Tokyo, Japan,* [2]*Nara National College of Technology, Japan,* [3]*Tokyo University of Science, Japan,* [4]*National Astronomical Observatory of Japan, Japan,* [5]*Institute of Space and Astronautical Science, Japan.*
11:20 AM - 11:30 AM

In a rich cluster of galaxies, hundred of member galaxies swim in the intra-cluster hot plasma with transonic speed. Since the moving galaxies carry their own inter-stellar plasma and possibly inter-stellar magnetic field, they may interact with the cluster plasma in form of ram pressure and/or magnetohydrodynamic turbulence. Such interaction will gradually transfer energy and momentum from galaxies to the cluster plasmas. Hence, the plasmas will be heated against radiative loss, while the stellar component is expected to become more and more concentrated towards cluster center.

To verify this conjecture, we studied the "optical-light vs. ICM-mass ratio" profile for a sample of 34 relaxed clusters with z=0.1-0.9. Using optical data obtained with the UH88 telescope and X-ray data with XMM-Newton and Chandra, we calculated the radially-integrated optical luminosity profiles and projected ICM mass profiles, respectively. We found that the light-to-ICM ratio profiles drop more steeply outwards in low redshift clusters. According a K-S test, the evolution is significant at >90% confidence level. By assessing systematic errors and biases, we found none of them is significant against the observed evolution. Furthermore, other astrophysical effects, e.g., dynamical friction, are estimated to be insufficient to explain the observation. This result provides important support for our view of galaxy-plasma interaction.

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508 – CMEs I

Oral Session – Room 4, Dena'ina Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

508.01 – **The Rayleigh-taylor Instability In The Solar Corona: Prominence Coronal-cavity Interactions And The Evolution To Eruptive States**

Thomas Berger[1]
[1]*Lockheed Martin Adv. Tech. Ctr..*
10:00 AM - 10:15 AM

We review the discovery and analysis of the Rayleigh-Taylor instability in quiescent solar prominences by the Hinode/SOT and SDO/AIA instruments. The instability is apparently caused by the emergence of magnetic flux near the polarity inversion line below the prominences. The emerging flux is rapidly heated to coronal temperatures of 1 MK or higher and the resulting large temperature gradient with the cool overlying prominence plasma leads to a "magneto-thermal" convective instability that develops into a classic Rayleigh-Taylor system of plumes and downflows. The significance of the discovery is that it offers a mechanism by which magnetic flux and helicity are periodically injected into the coronal cavity flux ropes overlying solar prominences. The increasing flux and helicity in the cavity develop a quasi-steady evolution eventually terminating in the eruption of a slow coronal mass ejection (Fan & Gibson 2007; Zhang, Flyer, & Low 2006). We suggest further investigations using SDO/AIA, ground-based observatories, and the upcoming IRIS mission to verify and extend the SOT and AIA findings.

508.02 – **Observations from *SDO* and *Hinode* of a Twisting and Writhing Start to a Solar-filament-eruption Cascade**

Alphonse C. Sterling[1], R. L. Moore[2]
[1]*NASA's MSFC, Japan,* [2]*NASA's MSFC.*
10:15 AM - 10:30 AM

We analyze data from *SDO* and *hinode* of a solar eruption sequence of 1 June 2011 near 16:00~UT, with emphasis on the early evolution toward eruption. Ultimately, the sequence consisted of three emission bursts and two filament ejections. *SDO*/AIA 304 Ang images show absorbing-material strands initially in close proximity that over ~ 20 min form a twisted structure, presumably a flux rope with ~10^{29} ergs of free energy that triggers the resulting evolution. A jump in the filament/flux rope's height (average velocity ~ 20 km s^{-1}) and the first burst of emission accompanies the flux-rope formation. After ~ 20 min more, the flux rope/filament kinks and writhes, followed by a semi-steady state where the flux rope/filament rises at (~ 5 km s^{-1}) for ~ 10 min. Then the writhed flux rope/filament again becomes MHD unstable and violently erupts, along with rapid (> 50 km s^{-1}) ejection of the filament and the second burst of emission. That ejection removed field that had been restraining a second filament, which subsequently erupts as the second filament ejection accompanied by the third (final) burst of emission. Magnetograms from *SDO*/HMI and *hinode*/SOT, and other data, reveal several possible causes for initiating the flux-rope-building

reconnection, but we are not able to say which is dominant. Our observations are consistent with tether-cutting reconnection initiating the first burst and the flux-rope formation, with MHD processes initiating the further dynamics. Both filament ejections are consistent with the standard model for solar eruptions.
NASA supported this work through its Heliophysics program.

508.03 – **Prior Flaring: A Complement to Free Magnetic Energy for Forecasting Solar Eruptions**

David Falconer[1], R. Moore[2], A. Barghouty[2], I. Khazanov[3]
[1]*UAHuntsville/MSFC,* [2]*NASA's MSFC,* [3]*UAHuntsville.*
10:30 AM - 10:45 AM

From a large database of (1) 40,000 SOHO/MDI line-of-sight magnetograms covering the passage of 1,300 sunspot active regions across the 30-degree radius central disk of the Sun, (2) a proxy of each active region's free magnetic energy measured from each of the active region's central-disk-passage magnetograms, and (3) each active region's full-disk-passage history of production of major flares and fast coronal mass ejections (CMEs), we find new statistical evidence that (1) there are aspects of an active region's magnetic field other than the free energy that are strong determinants of the active region's productivity of major flares and fast CMEs in the coming few days, (2) an active region's recent productivity of major flares, in addition to reflecting the amount of free energy in the active region, also reflects these other determinants of coming productivity of major eruptions, and (3) consequently, the knowledge of whether an active region has recently had a major flare, used in combination with the active region's free-energy proxy measured from a magnetogram, can greatly alter the forecast chance that the active region will have a major eruption in the next few days after the time of the magnetogram. The active-region magnetic conditions that in addition to the free energy are reflected by recent major flaring are presumably the complexity of the field configuration and facets of the evolution of the field.

This work has been funded by NASA's Heliophysics Division, NSF's Division of Atmospheric Sciences, and AFOSR's MURI Program. Development of this forecasting tool for JSC/Space Radiation Analysis Group was supported by NASA's Office of Chief Engineer Technical Excellence Initiative and is supported by NASA's AES (Advance Exploration Systems) Program.

508.04 – **Radio Imaging Of Shock-accelerated Electrons Associated With An Erupting Plasmoid On The 3rd Of November 2010**

Hazel Bain[1], S. Krucker[1], L. Glesener[1], R. P. Lin[1]
[1]*University of California, Berkeley.*
10:45 AM - 11:00 AM

We present observations of a metric type II solar radio burst that occurred in association with an erupting plasmoid on the 3rd of November 2010. The event was well observed by the Nancay Radioheliograph (NRH) and the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO). Events in which the type II emission is present in the NRH frequency range of a few hundred MHz are infrequent. From NRH images, we found the type II source location to be situated ahead of the hot (~11 MK) core of the plasmoid, which is surrounded by an envelope of cooler (few MK) plasma. Fitting the type II emission observed in radio spectrogram data, we were able to determine that the shock which produced the type II emission, was propagating with a velocity of 1900 - 2000 km/s. Using a combination of direct imaging from NRH and polarized brightness images from LASCO C2, we were able to normalize the coronal density model used for the fit. The shock velocity was found to be significantly greater than the velocity of the hot core and cooler envelope (670 - 1440 km/s) seen at extreme ultraviolet wavelengths with AIA. The location of the burst emission ahead of the core and the relative velocities of the shock and the plasmoid are indicative of a piston-driven shock.

This work was supported in part by the RHESSI project, NASA contract NAS598033. LG was partly supported by NASA GSRP grant NNX09AM40H. RPL was partly supported by the WCU grant (No. R31-10016) funded by the Korean Ministry of Education, Science and Technology.

508.05 – **Signatures Of Tether-cutting Reconnections In Pre-eruption Coronal Flux Ropes**

Yuhong Fan[1]
[1]*HAO/NCAR.*
11:00 AM - 11:15 AM

Using a 3D MHD simulation, we model the quasi-static evolution and the onset of eruption of a coronal flux rope. Earlier in the simulation, the emergence of a twisted flux rope is driven at the lower boundary into a pre-existing coronal potential arcade field. Then the emergence is stopped at the lower boundary and the coronal flux rope settles into a quasi-static rise phase with an underlying sigmoid-shaped current layer developing. Reconnections in the current layer during the quasi-static phase effectively reduce the anchoring of the flux rope and thus allow it to rise quasi-statically, even as the magnetic energy is decreasing. As a result of the reconnections, a central hot, low-density channel containing reconnected, twisted fields forms on top of the reconnecting current layer, and aligned with the current layer. When viewed in the direction along the central current layer (or along the neutral line) against the limb, the warped current layer appears as a narrow high-density vertical column with "horns" extending upward and enclosing a central low-density void on top of the column. Such density features have been observed within coronal prominence cavities, as described by Berger et al. and Regnier et al. Our MHD simulation suggests that they are the signatures and consequences of the tether-cutting reconnections, and that the central void grows and rises with the reconnections, until it reaches the critical height for the onset of the torus instability and dynamic eruption ensues.

508.06 – **Modeling Of Coronal Mass Ejection Generation And Acceleration With A High Fidelity Multi-fluid Code**

Vyacheslav Lukin[1], M. G. Linton[1]
[1]*Naval Research Laboratory.*
11:15 AM - 11:30 AM

Understanding of the physical mechanisms responsible for initiation of solar coronal mass ejections (CMEs) is critical for prediction of the strength and speed of CME-driven shocks and the flux of associated solar energetic particles throughout the heliosphere. Here, we present results of high fidelity numerical simulations of CME generation and acceleration via variations on the breakout CME initiation model using the state-of-the-art multi-fluid HiFi modeling framework. The breakout CME initiation mechanism is driven by flux injection and relies on magnetic reconnection as the necessary element in allowing CME flux ropes to elevate from the solar surface and escape through overlying magnetic fields. In this work we demonstrate that the global structure and evolution of CME magnetic fields is closely tied with the reconnection rate and local dynamics of the magnetic reconnection regions. In particular, it is shown that the rate of reconnection at the flare site behind the escaping flux rope is an important factor in determining the acceleration of the CME away from the solar surface, while capturing the heat conduction anisotropy is critical for accurate modeling of plasma temperature within the CME flux rope. Throughout, we emphasize the relationship and feedback mechanisms between the global and local scales, as well as investigate the sensitivity of the breakout model to the rate of magnetic flux injection at the solar surface.

This research is supported by NASA and the US Office of Naval Research.

509 – Flares I

Oral Session – Room 5, Dena'ina Center – 6/14/2012 10:00:00 AM to 6/14/2012 11:30:00 AM

509.01 – **Analysis and Modeling of Two Flare Loops Observed by AIA and EIS**

Ying Li[1], J. Qiu[1]
[1]*Montana State University.*
10:00 AM - 10:15 AM

We analyze and model an M1.0 flare observed by SDO/AIA and Hinode/EIS to investigate how flare loops are heated and evolve subsequently. The flare is comprised of two distinctive loop systems observed in EUV images. The UV 1600 angstrom emission at the feet of these loops exhibits a rapid rise, followed by enhanced emission in different EUV channels observed by AIA and EIS. Such behavior is indicative of impulsive energy deposition and the response in overlying coronal loops that evolve through different temperatures. Using the method we recently developed, we infer the heating functions from the rapid rise of the UV light curves for the two loop systems, respectively, treating them as two big loops of cross-sectional area 5" by 5", and compute the plasma evolution in the loops using the EBTEL model. We compute the synthetic EUV light curves, which well agree with observed light curves by AIA and EIS by within a factor of two. Furthermore, we also compare the computed mean enthalpy flow velocity with the Doppler shift measurements by EIS during the decay phase of the two loops. Our results suggest that the two different loops with different heating functions as inferred from their foot-point UV emission, combined with their different lengths as measured from imaging observations, give rise to different coronal plasma evolution patterns captured both in the model and observations.

509.02 – **Flare Ribbons In The Early Phase Of An SDO Flare: Emission Measure And Energetics**

Lyndsay Fletcher[1], I. G. Hannah[1], H. S. Hudson[2], D. E. Innes[3]
[1]*University of Glasgow, United Kingdom,* [2]*U. C. Berkeley,* [3]*Max-Planck Institute for Solar System Research, Germany.*
10:15 AM - 10:30 AM

We report on the M1.0 flare of 7th August 2010, which displayed extended early phase chromospheric ribbons, well observed by SDO/AIA and RHESSI. Most large flares saturate rapidly in the high-temperature AIA channels, however this event could be followed in unsaturated AIA images for ten minutes in the build-up to and first few minutes of the impulsive phase. Analysis of GOES, RHESSI and SDO/AIA demonstrates the presence of high temperature (~10MK), compact plasma volumes in the chromospheric flare ribbons, with a column emission measure of on average 3-7 x 10^{28} cm^{-5}. We construct a time-resolved energy budget for the ribbon plasma, including also SDO/EVE data, and discuss the implications of the observed ribbon properties for flare energisation.

This work was supported by the UK's Science and Technology Facilities Council (ST/1001801), and by the European Commission through the FP7 HESPE project (FP7-2010-SPACE-263086).

509.03 – **Investigating the Structure of Impulsive Phase Footpoints**

David Graham[1], I. Hannah[1], L. Fletcher[1], R. Milligan[2]
[1]*University of Glasgow, United Kingdom,* [2]*Queen's University Belfast, United Kingdom.*
10:30 AM - 10:45 AM

The location of flare heating in the solar atmosphere is imperative to understanding the heating mechanism. The differential emission measure is an

important tool in understanding the properties of flaring plasma. However, determining the DEM of impulsive phase footpoints has been difficult in the past without sufficient spatial resolution to resolve footpoints from loop structures, and a lack of spectral and temporal coverage. We use the capabilities of Hinode/EIS to present the first DEMs from the impulsive phase of a number of flare footpoints. Observations were chosen from a period when EIS telemetry was at its best and analysed using a new regularised inversion method (Hannah & Kontar 2012). We find a peak temperature in the DEM of around 7 MK with emission measures peaking between 10^28 and 10^29 cm-5, indicating a substantial presence of plasma at 'coronal' temperatures within the footpoint. In addition to the DEM, we perform a wide range of density diagnostics from transition region to coronal temperatures, allowing us estimate where in the atmosphere the EUV emission originates.

509.05 – **Constraining Differential Emission Measure and Energy Estimates for Microflares and Active Regions by Combining SDO/AIA and RHESSI**

Andrew Inglis[1], S. Christe[1], M. Aschwanden[2]

[1]*NASA Goddard Space Flight Center,* [2]*Lockheed Martin Advanced Technology Center.*

11:00 AM - 11:15 AM

Direct diagnostics of the fundamental parameters of solar coronal phenomena remains an active and challenging goal. Constrained, spatially resolved values of many parameters, such as the magnetic field strength, temperature, emission measure, and energy, are often difficult to achieve. However, the advent of the Atmospheric Imaging Assembly (AIA) on board SDO provides us with greater opportunity to pursue these measurements.

Here, we present differential emission measure (DEM) analysis of a selection of recent microflares and hot active regions, utilising a combination of high temperature RHESSI data, and forward-fitting temperature mapping, a procedure developed by Achwanden et al. (2011) for SDO/AIA. This procedure models the plasma temperature as a Gaussian distribution, and uses the instrument response functions to find the distribution which best reproduces the observed fluxes in each AIA wavelength. The accuracy of the method is examined, including an investigation of uncertainties and the temperature range over which the DEM is reasonably constrained. We also study the ability of the method to accurately represent the flux in all of the AIA wavelengths simultaneously. This technique is combined with RHESSI spectral data to produce complementary time-dependent DEM measurements for four microflares from June - August 2011, and one set of post-flare loops from 2010 October 16. In general, the high temperature emission measure fitted by RHESSI has a steeper spectral index than that observed with AIA. However, we illustrate how the high temperature RHESSI data can be used to further inform the AIA fitting procedure, improving the results. We also expand on the AIA forward fitting to produce spatial energy maps of microflares and active regions, also allowing estimates of the total energy of these regions to be made.

509.06 – **Evidence of 3-D Reconnection at Null Point from the Observations of Circular Flares and Homologous Jets**

Haimin Wang[1], C. Liu[1]

[1]*NJIT.*

11:15 AM - 11:30 AM

In recent studies by Pariat, Antiochos and DeVore (2009, 2010), fan-separatrix topology and magnetic reconnection at the null-point were simulated and found to produce homologous jets. This motivates us to search for axisymmetric magnetic structure and associated flaring/jetting activity. Using high-resolution (~0.15" per pixel) and high-cadence (~15 s) H-alpha center/offband observations obtained from the recently digitized films of Big Bear Solar Observatory, we were able to identify five large circular flares with associated surges. All the events exhibit a central parasite magnetic field surrounded by opposite polarity, forming a circular polarity inversion line (PIL). Consequently, a compact flare kernel at the center is surrounded by a circular ribbon, and together with the upward ejecting dark surge, these seem to depict a dome-like magnetic structure. Very interestingly, (1) the circular ribbon brightens sequentially rather than simultaneously, (2) the central compact flare kernel shows obvious motion, and (3) a remote elongated, co-temporal flare ribbon at a region with the same polarity as the central parasite site is seen in the series of four homologous events on 1991 March 17 and 18. The remote ribbon is ~120" away from the jet location. Moreover, magnetic reconnection across the circular PIL is evident from the magnetic flux cancellation. These rarely observed homologous surges with circular as well as central and remote flare ribbons provide valuable evidence concerning the dynamics of magnetic reconnection in a null-point topology.

This study is dedicated to Professor Hal Zirin, the founder of Big Bear Solar Observatory, who passed away on January 3, 2012.

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510 – Yup'ik Understandings of the Environment: "The World is Changing Following Its People"

Invited Session – Ballroom B, Dena'ina Center – 6/14/2012 11:40:00 AM to 6/14/2012 12:30:00 PM

510.01 – **Yup'ik Understandings of the Environment: "The World is Changing Following Its People."**

Ann Fienup-Riordan[1]

[1]*Arctic Studies Center.*

11:40 AM - 12:30 PM

My talk describes a decade of work with Yup'ik elders sponsored by the Calista Elders Council, the primary heritage organization in southwest Alaska. Our goal was to document the qanruyutet (instructions) that continue to guide Yup'ik interactions with ella--translated variously as weather, world, universe, and awareness. Elders addressed a range of topics, including weather, land, lakes and rivers, ocean, snow, ice, survival, environmental change, and of course stars. Many elders suffer over the fact that contemporary young people lack knowledge of ella. They actively support the documentation and sharing of traditional knowledge, which all view as possessing continued value in the world today.

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511 – Bridging Laboratory and Astrophysics: Particles

Meeting-in-a-Meeting – Summit Hall 1, Egan Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

Laboratory astrophysics is the Rosetta Stone that enables astronomers tounderstand and interpret the cosmos. This session will focus on theinterplay between astrophysics with theoretical and experimental studiesinto the underlying particle physics processes which drive our cosmos.

511.01 – **Theories of Dark Matter and Their Implications for Astrophysical Observables**

Kathryn Zurek[1]

[1]*University of Michigan.*

2:00 PM - 2:30 PM

I review the present status of theories of dark matter, discuss laboratory probes of these theories at the LHC and in underground direct detection experiments, and examine astrophysical probes that could constrain and advance our understanding of these theories.

511.02 – **New Constraints on Temporal Variation of the Fine-Structure "Constant" from the Laboratory Search with Dy**

Dmitry Budker[1], N. Leefer[1], A. Cingöz[2], C. T. M. Weber[1]

[1]*University of California, Berkeley,* [2]*JILA.*

2:30 PM - 3:00 PM

Atomic dysprosium is a unique system with nearly degenerate opposite-parity states that have large and oppositely-signed sensitivity to a variation of α, lending itself to a possibility of a sensitive test for a variation of a fundamental constant [1], which does not rely on a particularly sensitive clock. Building upon our earlier results [2] constraining the variation at a few parts per 1015 per year level (competitive with the state-of-the-art at that time), we conducted a new, at least an order of magnitude more sensitive search, the results of which will be presented at the meeting. A study of a systematic effect associated with the level shifts due to the black-body radiation will also be discussed.

[1] V. A. Dzuba, V. V. Flambaum, and J. K. Webb, Phys. Rev. Lett. 82, 888 (1999).

[2] A. Cingöz, N.A. Leefer, S.J. Ferrell, A. Lapierre, A.-T. Nguyen, V. V. Yashchuk, D. Budker, S. K. Lamoreaux, and J. R. Torgerson, A laboratory search for variation of the fine-structure constant using atomic dysprosium, Eur. Phys. J. Special Topics 163, 71-88 (2008).

511.03 – **Ultra-High Energy Cosmic Rays**

Christopher Williams[1]

[1]*University of Chicago.*

3:00 PM - 3:30 PM

After a century of observations, the origin of cosmic rays remains a mystery. At the highest energies, sources should be among the most powerful extragalactic accelerators. Large observatories have revealed a flux suppression above a few 10^{19} eV similar to the expected effect of the interaction of ultrahigh energy cosmic rays (UHECR) with the cosmic microwave background. The Pierre Auger Observatory has measured the largest sample of cosmic ray induced extensive air showers (EAS) at the highest energies leading to a precise measurement of the energy spectrum, hints of spatial anisotropy, and a surprising change in the chemical composition at the highest energies. To answers the question of the origin of UHECRs a larger sample of high quality data will be required to reach a statistically significant result. I will present a review of the measurements made to date and the laboratory experiments required to reach this high level of precision. These experiments include precise measurements of air fluorescence properties made using a multitude of test beam measurements at particle accelerators and precise monitoring of atmospheric conditions at the observatory site. I will also review the interplay between UHECR science and high energy physics, which has led to new measurements of fundamental interactions and brought about new questions as we seek to understand particle interactions at energies which are currently not obtainable in the laboratory. Finally, I will present an outlook on the future of UHECR observatories and the laboratory experiments that will be required to build the next generation of detectors as we seek to find the origin and composition of cosmic rays at the highest energies.

512 – Lyman Alpha Emitters as Probes of Galaxy Formation and Cosmology: Studying Reionization

Meeting-in-a-Meeting – Summit Hall 2, Egan Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

Three 20+5 minute talks will be given summarizing how Lyman Alpha Emitters (LAEs) are being used to characterize the epoch of reionization. The so-called "red damping wing" of a fully neutral IGM absorbs almost all Lyman Alpha photons that escape a galaxy, so very few LAEs should be found in neutral regions. This predicts strong observable features in terms of large-scale LAE clustering when the universe is only partially reionized and a rapid drop in the LAE luminosity function as the redshift of reionization is reached. Current observational constraints will be described. The session will conclude with a 15-minute moderated discussion of outstanding questions and how to resolve them.

512.01 – **Reionization History and Physical Processes Indicated from the Census of Lyα Emitters at z~7**

Masami Ouchi[1]

[1]*University of Tokyo, Japan.*

2:00 PM - 2:25 PM

I review the results from our Subaru-Keck deep wide-field survey that has made the largest sample, to date, of >200 Lyα emitters (LAEs) at z=6.5-7.31 in a large >1 deg^2 area. The reionization history is discussed based on evolution of luminosity function, clustering, and Lyα line profiles including errors of statistics and cosmic variance robustly estimated from our large LAE sample. The reionization process is studied with Lyα emitting galaxy fraction. The evolution of Lyα emitting galaxy fraction drops from z~6 to 7, and the amplitude of the drop is larger for faint galaxies than for bright galaxies. These two pieces of evidence would indicate that the neutral hydrogen fraction of the intergalactic medium increases from z~6 to 7 and that the reionization proceeds from high- to low-density environments, as suggested by an inside-out reionization model. At the last part of my talk, I introduce our planned survey for about ten thousand spectroscopically-confirmed LAEs at z~7 covering a total of ~30 deg^2 (~1 Gpc x 1 Gpc) area with the next generation Subaru prime-focus imager and spectrograph.

512.02 – **Studying Reionization using Lyman Alpha Galaxies**

James E. Rhoads[1]

[1]*Arizona State Univ..*

2:25 PM - 2:50 PM

Resonant scattering of Lyman alpha photons by neutral hydrogen hides Lyman alpha emission lines from view prior to the epoch of reionization. This simple principle provides us with several ways to study the history of reionization. These include the Lyman alpha luminosity function, observed spatial distributions of Lyman alpha emitters, Lyman alpha equivalent width distributions, and the minimum ionized volume test. I will present a brief overview of the underlying physics, the context from other reionization methods, and the observational constraints so far from the various Lyman-alpha based tests. I will then discuss our group's ongoing Lyman alpha searches at z ~ 8. Finally, I will discuss recent results on characterizing the distribution of velocity offsets between the Lyman alpha line and the systemic velocity-- a quantity that plays an important role in interpreting the results of Lyman-alpha based reionization tests.

512.03 – **Probing Reionization with Deep Spectroscopy**

Daniel Stark[1]

[1]*Caltech.*

2:50 PM - 3:15 PM

The Hubble Space Telescope has recently revealed the first large samples of star forming galaxies in the redshift range 7<z<9, providing useful constraints on the contribution of galaxies to the reionization of intergalactic hydrogen. Hindering efforts to determine whether galaxies are the primary ionizing sources responsible for this transition is our poor understanding of the window over which reionization occurs. To address this shortcoming, we have been obtaining deep spectroscopic measures of Lyman-alpha emission in the new samples of galaxies discovered by HST. Owing to the resonant interaction of Lyman-alpha with neutral hydrogen, we expect the fraction of continuum-selected galaxies with strong Lyman-alpha emission to decrease in the reionization era. I will review the latest results from these observational campaigns and discuss the implications for the timescale of reionization.

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513 – Star Clusters and the Milky Way

Oral Session – Room 1, Dena'ina Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

513.01 – **A Comparison Between the Universal and Environmental Models for the Formation and Destruction of Star Clusters**

Bradley C. Whitmore[1], R. Chandar[2]

[1]*STScI,* [2]*U. of Toledo.*

2:00 PM - 2:10 PM

Two basic frameworks have been developed to explain the formation and early destruction of star clusters in the past several years. The "universal" or "quasi-universal" framework takes its lead from the apparent similarity of luminosity, mass, and age distributions in a growing number of galaxies (e.g., Antennae, M83, M51, Magellanic Clouds, Milky Way, ...). This model argues that the similarity indicates that the dominant influences controlling star cluster demographics are physical processes internal to the cluster (e.g., removal of the ISM, stellar evolution mass loss, ...) rather than external influences (e.g, ambient density, shock heating, ...). While environmental influences are clearly expected, it is argued that the dominant first-order influences need to be understood before the second-order effects can be extracted. The environmental framework takes its lead from apparent curvature in the age and mass distributions of some data sets, and hence argues that external influences play the dominant role. In the past it has been difficult to compare the two frameworks since different datasets and different selection effects have generally been used. In this contribution I will focus on recent WFC3 data of M83, where two different groups are using the same data and have taken the initiative to better compare analysis techniques and the role that selection effects play on the resulting mass and age distributions.

513.02 – **Stellar-Mass Black Holes in Dense Star Clusters**

Meagan Morscher[1], F. Rasio[1]

[1]*Northwestern University.*

2:10 PM - 2:20 PM

Globular Clusters with core-collapse times longer that the lifetime of the most massive stars can are thought to produce many stellar-mass black holes (BH) and retain most of them initially. The dynamical evolution of stellar BHs in clusters is important for studies of merging BH-BH binaries, which will be detectable by future gravitational wave observatories. Since BHs are among the most massive objects in a cluster, they tend to sink to the center through two-body relaxation, forming a dense core in which BH-BH binaries can be formed, destroyed, and ejected. The fate of BHs in clusters, however, is still highly uncertain. Only recently have dynamics codes become powerful enough to simulate clusters with realistic N, full stellar mass spectra, and significant numbers of primordial binaries. Using a Monte Carlo method, we model realistic star clusters with stellar-mass BHs. We discuss the evolution of BH populations within clusters, as well as the implications for gravitational wave astronomy.

513.03 – **Evidence for Gamma-ray Jets in the Milky Way**

Meng Su[1]

[1]*Harvard University.*

2:20 PM - 2:30 PM

Although accretion onto supermassive black holes in other galaxies is seen to produce powerful jets in x-ray and radio, no convincing detection of a jet has ever been made in the Milky Way. The recently discovered pair of 10 kpc tall gamma-ray bubbles in our Galaxy may be signs of earlier jet activity from the central black hole. I will present our recent work that identifies a gamma-ray cocoon feature in the southern bubble, a jet-like feature along the cocoon’s axis of symmetry, and another directly opposite the Galactic center in the north. The cocoon and jets have a hard spectrum from 1-100 GeV, with a cocoon luminosity of 5.5 ± 0.5 × 10^35 erg/s and total jet luminosity of 1.8 ± 0.3 × 10^35 erg/s at 1-100 GeV. If confirmed, these jets are the first resolved gamma-ray jets ever seen.

513.04 – **Searching For Stellar Clusters in Extreme Environments**

Duilia F. De Mello[1]

[1]*Catholic University of America.*

2:30 PM - 2:40 PM

I will report the latest results of our project searching for stars born in clusters outside galaxies. Very often, when galaxies collide/merge/interact, their neutral gas, HI, is stripped out of them and found in extended tidal tails in the intergalactic medium. At first glance these gas clouds look empty and even detached from the galaxies. Recently, we have found out that this is not always the case. We used the GALEX ultraviolet satellite to search within HI tails in a sample of interacting galaxies and detected several young stellar clusters and even dwarf galaxies in the process of formation. Our team has analyzed multiwavelength data (Gemini, SDSS, VATT) of these objects showing that they are young and metal rich. Our main conclusion is that they were formed “in situ” from pre-enriched material that was ejected from the galaxies during interaction. These nurseries can be (i) the precursors of globular clusters, (ii) dwarf galaxies in the process of formation or (iii) dissolve and not remain gravitationally bound, yielding only very sparse star streams.

513.05 – **Proper Motions Of The Arches Cluster With Keck Lgs-adaptive Optics: The First Kinematic Mass Measurement Of The Arches**

Will I. Clarkson[1], A. Ghez[2], M. Morris[2], J. Lu[3], A. Stolte[4], N. McCrady[5], T. Do[6], S. Yelda[2]

[1]*Indiana University, Bloomington,* [2]*University of California, Los Angeles,* [3]*University of Hawaii,* [4]*Argelander Institut fur Astronomie, Universitat Bonn, Germany,* [5]*University of Montana,* [6]*University of California, Irvine.*

2:40 PM - 2:50 PM

We report the first detection of the intrinsic velocity dispersion of the Arches

cluster - a young (~2 Myr), massive (~10,000 Solar Mass) starburst cluster located near the Galactic center. This was accomplished using proper motion measurements within the central 10'' by 10'' region of the cluster, obtained with the Keck Observatory laser guide star adaptive optics system over a 3 year time baseline (2006-2009). This uniform dataset results in proper motion measurements that are improved by a factor ~5 over previous measurements from heterogeneous instruments, yielding internal velocity dispersion estimates 0.15 +/- 0.01 mas/yr, which corresponds to 5.4 +/- 0.4 km/s at a distance of 8.4 kpc.

Projecting a simple model for the cluster onto the sky, in conjunction with surface density data, we estimate the total present-day mass of the cluster to be 15,000 (+7400 -6000) Solar masses. The mass in stars observed within a cylinder of radius R=0.4 pc is found to be 9000 (+4000 -3500) Solar Masses at formal 3-sigma confidence. This mass measurement is free from assumptions about the mass function of the cluster, and thus may be used to check mass estimates from photometry and simulation. When we conduct this check, we find that the present-day mass function of the Arches cluster is likely either top-heavy or truncated at low-mass, or both.

Collateral benefits of our data and analysis include: (i) cluster membership probabilities, which may be used to extract a clean cluster sample for future photometric work; (ii) a refined estimate of the bulk motion of the Arches cluster with respect to the field, of 172 +/- 15 km/s, which is slightly slower than suggested by previous VLT-Keck measurements; and (iii) a velocity dispersion estimate for the field itself, which is likely dominated by the inner galactic bulge and the nuclear disk.

513.06 – **Radial Velocities of Very Metal-Poor Stars as Probes of the Dual Halo Model of the Milky Way**

Timothy C. Beers[1], M. Juric[2], D. Carollo[3], Y. Lee[4], D. An[5], W. Aoki[6], J. E. Norris[7], D. Yong[7]

[1]NOAO/JINA, [2]LSST, [3]Macquarie Univ., Australia, [4]Michigan State Univ./JINA, [5]Ehwa Womans Univ., Korea, Republic of, [6]NAOJ, Japan, [7]RSAA, Australian National Univ., Australia.
2:50 PM - 3:00 PM

We consider the distribution of radial velocities (RVs) for a large sample of very metal-poor stars from SDSS/SEGUE (N > 25000 with [Fe/H]< -2.0, of which ~ 900 have [Fe/H] < -3.0), and two smaller recent high-resolution spectroscopic studies of the most metal-poor stars known (N > 300, of which ~ 150 have [Fe/H] < -3.0). The RVs are compared with the expected

behavior obtained using the GALFAST code of Juric, under the assumption that the halo of the Milky Way comprises a single population with canonical kinematics (e.g., as described by Chiba & Beers 2000). We find clear evidence that the RVs of these stars are inconsistent with draws from such a model, and that they appear to require at least a two-component halo.

This test is, by design, independent of questions related to assignment of estimated stellar distances, or selection criteria related to proper motions, and provides strong support of the dual halo model described by Carollo et al. (2007, 2010).

513.07 – **Vibrationally Excited HCN in the Galactic Center Circumnuclear Disk**

Elisabeth A. Mills[1], M. R. Morris[1], R. Güsten[2]

[1]UCLA, [2]Max-Planck-Institut für Radioastronomie, Germany.
3:00 PM - 3:10 PM

Recent GREAT observations of CO in the Galactic center Circumnuclear Disk (CND) indicate that this structure is transitory, having gas densities on the order of 10^4 to 10^5 cm^-3, much less than those previously determined using high-density tracers such as HCN. We investigate this discrepancy with new HCN data from the APEX telescope in which we detect for the first time vibrationally-excited transitions of HCN in the CND. This suggests that the source of the disagreement in densities inferred from CO and HCN is the assumption that collisional excitation dominates the excitation of both molecules. We find that radiative excitation of HCN is an important contributor in the environment of the CND. We model the radiative excitation using observed rotational lines of HCN and H13CN from J=3-2 to J=8-7 in both the vibrational ground state and the v2=1 excited state. Our results suggest that ignoring radiative pumping from a strong infrared radiation field, such as in the Galactic center or actively star forming galaxies, can lead to overestimates of the density when using HCN and similar molecules.

514 – Galaxy Clusters II

Oral Session – Ballroom A, Dena'ina Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

514.01 – **A3571, The Brightest Line of Sight Bullet?**

Renato A. Dupke[1], A. Elvas[2], J. Irwin[3]

[1]Univ. of Michigan / Univ. Alabama/ National Observatory Brazil/Eureka Scientific, [2]National Observatory, Brazil, Brazil, [3]Univ. of Alabama.
2:00 PM - 2:10 PM

Abell 3571 is one of the richest and hottest clusters in the Shapley Supercluster. At a redshift of ~0.04 it is the 6th brightest cluster in the X-ray sky. Despite being a B-M type I and apparently well behaved, evidence for dynamic activity in the cluster has been increasing both from the optical and X-ray observations.

Here, we show the results of spatially resolved spectroscopy from a relatively shallow Chandra observation of A3571. We show that the temperature distribution has a strongly bi-modal distribution around the NE-SW axis crossing the central region, strongly suggesting that a strong merger is happening . The distribution of density, abundances and gas velocities support a scenario where the merging is transonic-supersonic with the axis is near the line of sight.

514.03 – **Using Numerical Simulations to Asses the Importance of High Resolution SZ Observations of Merging Galaxy Clusters**

Sandor M. Molnar[1]

[1]Leung Center for Cosmology and Particle Astrophysics, Taiwan.
2:20 PM - 2:30 PM

The distribution and evolution of galaxy clusters, due to their large masses, are very sensitive to the underlying assumed cosmological model. As a consequence, they have been used extensively to constrain cosmological parameters. However, when clusters are used for cosmology, they are assumed to be in hydrostatic equilibrium. Merging galaxy clusters are clearly not in equilibrium, therefore they may cause bias in the determination of cosmological parameters. Based on self-consistent N-body-hydrodynamical simulations, we discuss the importance of high angular resolution observations of merging galaxy clusters in identifying merging clusters.

514.04 – **Suzaku Observations to the Virial Radius of Fossil Group ESO3060170**

Yuanyuan Su[1], R. White[1], E. Miller[2], L. Gu[3]

[1]University of Alabama, [2]MIT, [3]University of Tokyo, Japan.
2:30 PM - 2:40 PM

"Fossil" galaxy groups, each dominated by a relatively isolated giant elliptical galaxy, have many properties intermediate between groups and clusters of galaxies. We used the Suzaku X-ray observatory to observe the X-ray brightest fossil group, ESO 3060170, out to its virial radius. We determined the temperature, gas density, and metal abundance distributions of the intracluster gas and derived the entropy, pressure and mass profiles. The entropy and pressure profiles in the outer regions are flatter than in simulated clusters, which may indicate the gas is clumpy, as found in some massive clusters. While the gas in most groups has smaller iron mass-to-light ratios (IMLR) than in clusters, the integrated IMLR of this fossil group achieves the cluster value. Thus, unlike most groups, this fossil group has retained nearly all of its metals. A galaxy density map on a scale of 15 Mpc shows that this fossil group resides in a relatively isolated environment, unlike the filamentary structures in which clusters are embedded.

514.05 – **Initial Results from a Very Deep Chandra Observation of the Galaxy Group NGC 5813**

Scott W. Randall[1], P. Nulsen[1], T. Clarke[2], W. Forman[1], C. Jones[1], M. Donahue[3], S. Giacintucci[4], E. Blanton[5]

[1]Center for Astrophysics, [2]Naval Research Laboratory, [3]Michigan State University, [4]University of Maryland, [5]Boston University.
2:40 PM - 2:50 PM

I will present initial results from a deep (650 ks) Chandra observation of the galaxy group NGC 5813, the deepest Chandra observation of a galaxy group core to date. This unique system shows three pairs of collinear cavities in the intragroup medium (IGM), with two of the pairs associated with elliptical outburst shock fronts. It is therefore ideal for studying AGN feedback and the outburst history of the central AGN. Measurements of the shock heating at each shock front show that shocks alone are enough to offset radiative cooling of the gas indefinitely, within at least the central 15 kpc. The internal energy of the cavities is not required, and is likely deposited in the IGM at larger radii. This demonstrates that shock heating can play an important role in the AGN feedback process, particularly at smaller radii, close to the central AGN.

514.06 – **The Virgo Cluster Through The AGES**

Rhys Taylor[1]

[1]NAIC, Arecibo Observatory.
2:50 PM - 3:00 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 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". I compare the HI mass function from AGES and ALFALFA within the Virgo Cluster, and show that AGES detects significantly more low-mass objects.

515 – CMEs II

Oral Session – Room 4, Dena'ina Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

515.01 – **SDO/AIA Detection of Quasi-periodic Wave Trains Within Global EUV ("EIT") Waves and Their Coronal Seismology Implications**

Wei Liu[1], L. Ofman[2], M. J. Aschwanden[3], N. Nitta[3], C. J. Schrijver[3], A. M. Title[3], T. D. Tarbell[3]

[1]*Stanford-Lockheed Institute for Space Research,* [2]*Catholic University of America and NASA Goddard Space Flight Center,* [3]*Lockheed Martin Solar and Astrophysics Laboratory.*
2:00 PM - 2:15 PM

The nature of global EUV waves (so-called "EIT waves") has long been under debate because of instrumental limitations and projection effects when viewed on the solar disk. We present here high cadence SDO/AIA observations of global EUV waves occurring on the limb. We report newly discovered quasi-periodic wave trains located in the low corona within a broad, diffuse pulse of the global EUV wave ahead of the lateral CME front/flank. These waves coherently travel to large distances on the order of 1 solar radii with initial velocities up to 1400 km/s. They have dominant 1-3 minute periodicities that often match the X-ray pulsations of the accompanying flare, suggestive of a causal connection. In addition, recently discovered quasi-periodic fast propagating (QFP) waves of 1000-2000 km/s (Liu, Title, Zhao et al. 2011 ApJL) are found in the funnel of coronal loops rooted at the flare kernel. These waves are spatially confined within the CME bubble and rapidly disappear while approaching the CME front, suggestive of strong damping and/or dispersion. These observations provide new evidence of the fast-mode wave nature of the primary, fast component of a global EUV wave, running ahead of a secondary, slow component of CME-caused restructuring of the coronal magnetic field. We suggest that the two types of quasi-periodic waves are both integral parts of global coronal dynamics manifested as a CME/flare eruption, and they have important implications for global and local coronal seismology.

515.02 – **Large-scale Coronal Disturbances As Observed By SDO AIA**

Nariaki Nitta[1], C. Schrijver[1], A. title[1], W. Liu[2], J. Lemen[1]
[1]*Lockheed Martin, ATC,* [2]*Lockheed Martin ATC/Stanford U.*
2:15 PM - 2:30 PM

With increasing solar activity, the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO) has observed a number of large-scale coronal disturbances, which may correspond to what we have generally known as "EIT waves." Their nature is still actively debated. In certain cases, the fronts of the disturbances may signify CME-related shock waves that are important for particle acceleration. Using the unprecedented temporal resolution and broad temperature coverage of the AIA, we have studied more than 100 such events. Here we discuss their kinematics characterized by faster fronts than EIT waves in Solar Cycle 23, and spatial relations with CMEs using STEREO data that provide triangulation of the fronts. We also try plasma diagnostic using images in different filters. Association of these disturbances with other phenomena such as CMEs, flares and type II bursts, is discussed on a statistical basis.

515.03 – **New High-Accuracy Methods for Automatically Detecting & Tracking CMEs**

Jason Byrne[1], H. Morgan[2], S. R. Habbal[1]
[1]*Institute for Astronomy,* [2]*University of Aberystwyth, United Kingdom.*
2:30 PM - 2:45 PM

With the large amounts of CME image data available from the SOHO and STEREO coronagraphs, manual cataloguing of events can be tedious and subject to user bias. Therefore automated catalogues, such as CACTus and SEEDS, have been developed in an effort to produce a robust method of detection and analysis of events. Here we present the development of a new CORIMP (coronal image processing) CME detection and tracking technique that overcomes many of the drawbacks of previous methods. It works by first employing a dynamic CME separation technique to remove the static background, and then characterizing CMEs via a multiscale edge-detection algorithm. This allows the inherent structure of the CMEs to be revealed in each image, which is usually prone to spatiotemporal crosstalk as a result of traditional image-differencing techniques. Thus the kinematic and morphological information on each event is resolved with higher accuracy than previous catalogues, revealing CME acceleration and expansion profiles otherwise undetected, and enabling a determination of the varying speeds attained across the span of the CME. The potential for a 3D characterization of the internal structure of CMEs is also demonstrated.

515.04 – **Quantitative Imaging of the Solar Wind: CME Mass Evolution and the Interplanetary Magnetic Flux Balance**

Craig DeForest[1]
[1]*Southwest Research Inst..*
2:45 PM - 3:00 PM

We recently developed post-processing techniques for heliospheric images from the STEREO spacecraft; the new data sets enable, for the first time, quantitative photometric studies of evolving wind features at distances up to 1 A.U. from the Sun. We have used the new data to trace several CMEs and magnetic disconnection events to their origins in the solar corona, and to infer the force balance and entrained magnetic flux in those features. We present recent results showing the relationship between ICME and CME anatomy, in particular the origin of an observed interplanetary flux rope and the relationship between original launched solar material and piled-up sheath material and flux in the storm at 1. A.U. We discuss implications for understanding space weather physics and predicting individual events, and point out the importance of future imaging technologies such as polarized heliospheric imaging.

515.05 – **On the Relationship Between Coronal Magnetic Decay Index and CME Speed**

Yan Xu[1], C. Liu[1], J. Jing[1], H. Wang[1]
[1]*New Jersey Institute of Tech..*
3:00 PM - 3:15 PM

Numerical simulations suggest that kink and torus instabilities are closely associated with initiation and prorogation of eruptive events. A magnetic parameter named "decay index" could play an important role in controlling kinematics of eruptions. It is defined as the coronal magnetic gradient of the overlying fields above the eruptive flux ropes. Previous studies have shown a threshold of the decay index that distinguishes the eruptive and confined configurations. In this study, we investigate if there is a clear correlation between the decay index and CME speed. 30 CMEs associated with filament eruptions are selected using the H-alpha data from the Global H-alpha Network. The filaments observed in H-alpha before eruptions help to locate the magnetic polarity inversion line, along which the decay index is calculated based on the potential field extrapolation using MDI magnetograms as boundary condition. The speeds of CMEs are derived from LASCO C2 observations. We discuss the statistical significance of how the CME speed varies with the magnetic decay index of the fields overlying the eruptive filaments.

516 – Flares II

Oral Session – Room 5, Dena'ina Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

516.01D – **Determine the Heating Rate in Reconnection Formed Flare Loops of the M8.0 flare on 2005 May 13**

Wenjuan Liu[1], J. Qiu[1], D. W. Longcope[1], A. Caspi[2]
[1]*Montana State University,* [2]*LASP, University of Colorado.*
2:00 PM - 2:20 PM

Many eruptive flares exhibit two extended ribbons in the lower-atmosphere outlining the feet of the post-flare coronal arcade. High-cadence and high-resolution UV observations by TRACE reveal that the flare ribbon consists of small patches sequentially brightened along the ribbon, suggesting that reconnection takes place sequentially forming individual post-flare loops along the arcade, as often seen in coronal observations in the EUV wavelengths. These reconnection events and formation of new loops continue well into the decay phase. Our recent study further shows that the spatially resolved UV brightness at the foot-points of individual loops grows rapidly on timescales of a few minutes, followed by a long decay on timescales of more than 10 minutes. The rapid rise of UV radiation is correlated with the hard X-ray light curve during the impulsive phase, hence is most likely a direct response of instantaneous heating in the reconnection formed flux tubes. In this study, we utilize the spatially resolved UV brightness time profiles to reconstruct instantaneous heating functions of a few thousand flux tubes anchored at the UV foot-points, and compute plasma evolution in each flux tube using the EBTEL model (Klimchuk et al. 2008). The temperature and density of these flux tubes are then used to calculate coronal radiation. The computed soft X-ray spectra and light curves compare favorably with those observed by RHESSI and GOES. The time-dependent transition region DEM for each tube during its decay phase is also computed and used to calculate optically-thin transition region line emissions, which are compared with UV observations at the decay phase. This study presents a method to constrain heating functions of reconnection formed flare loops using all available observables, and provides a powerful way to examine physics of heating discrete flux tubes.

516.02 – **Re-interpretation Of Supra-arcade Downflows In Solar Flares**

Sabrina Savage[1], D. E. McKenzie[2], K. K. Reeves[3]
[1]*NASA Goddard/ORAU,* [2]*Montana State University,* [3]*Harvard-Smithsonian Center for Astrophysics.*
2:20 PM - 2:35 PM

Following the eruption of a filament from a flaring active region, sunward-flowing voids are often seen above developing post-eruption arcades. First discovered using the soft X-ray telescope aboard Yohkoh, these supra-arcade downflows (SADs) are now an expected observation of extreme ultra-violet and soft X-ray coronal imagers and spectrographs (e.g, TRACE, SOHO/SUMER, Hinode/XRT, SDO/AIA). Observations made prior to the operation of AIA suggested that these plasma voids (which are seen in contrast to bright, high-temperature plasma associated with current sheets) are the cross-sections of evacuated flux tubes retracting from reconnection sites high in the corona. The high temperature imaging afforded by AIA's 131, 94, and 193 Angstrom channels coupled with the fast temporal cadence allows for unprecedented scrutiny of the voids. For a flare occurring on 2011 October 22, we provide evidence suggesting that SADs, instead of being the cross-sections of relatively large, evacuated flux tubes, are actually wakes (i.e., trailing regions of low density) created by the retraction of much thinner tubes. This re-interpretation is a significant shift in the fundamental understanding of SADs, as the features once thought to be identifiable as the shrinking loops themselves now appear to be "side effects" of the passage of the loops through the supra-arcade plasma. In light of the fact that previous measurements have attributed to the shrinking loops characteristics that may instead belong to their wakes, we discuss the implications of this new interpretation on previous parameter estimations and on reconnection theory.

516.03 – **Do We Understand Why Most Solar Flares Do Not Generate Quakes?**

Alina Donea[1], C. Lindsey[2]
[1]*Monash University, Australia,* [2]*CORA/North West Research Associates.*
2:35 PM - 2:50 PM

While some flares release power seismic transients into the solar interior, it is clear that only a minority of even X-class flares do this. Strangely, some major flares of the past cycle 23 were seismically inactive. For cycle 24, we undertake a comparative multiwavelength analysis of a seismically powerful flare and a seismically inactive one, to understand, observationally and physically, the basic properties that distinguish acoustically active flares and the physics that determines why some flares release powerful seismic transients while others do not. Mechanisms of seismic generation will be discussed, focusing on the roles of thick-target heating by high-energy particles, radiative heating by white-light emission, and Lorentz-force transients.

516.04 – **Stochastic Particle Acceleration by Helical Turbulence in Solar Flares**

Gregory D. Fleishman[1], I. N. Toptygin[2]
[1]NJIT, [2]State Polytechnical University, Russian Federation.
2:50 PM - 3:05 PM

Modern X-ray and radio observations favor a stochastic (Fermi) acceleration mechanism of fast particles produced in flares, which implies that an accelerating turbulence must somehow be generated by the primary flare energy release. The very release of free magnetic energy is only possible if the magnetic field deviates from a potential one. We show that this magnetic field nonpotentiality, via its corresponding current helicity, necessarily results in a noticeable kinetic helicity of the turbulence generated at the flare site by the primary energy release. We study the role of the turbulence helicity on the particle acceleration and find that a nonzero turbulence helicity has a remarkably strong effect on the particle acceleration. The main reason for this strong helicity effect is that the helical component of the turbulence induces, through a well-known alpha-effect, a regular large-scale electric field capable of directly accelerating charged particles (like in the models with DC field acceleration). We estimate the turbulence kinetic helicity based on measured photospheric and extrapolated values of the current helicity and take into consideration the helical turbulence effect on stochastic particle acceleration. We find that this induced large-scale electric field can be comparable with the electron and estimated effective ion Dreicer fields, which has an immediate effect on charged particle extraction from the thermal pool and their injection into stochastic acceleration process. We have discovered that this, so far missing but highly important, ingredient of the particle stochastic acceleration by turbulence at the flare site is naturally consistent with such puzzling flare manifestations as spatial separation of electron and proton emission sites, electron beam formation, and enrichment of the accelerated particle population by ^{3}He and other tiny ions.

This work was supported in part by NSF grant AGS-0961867 and NASA grant NNX10AF27G to New Jersey Institute of Technology.

516.05 – **Rapid Changes of Photospheric Magnetic Field after Tether-cutting Reconnection and Magnetic Implosion**

Chang Liu[1], N. Deng[1], R. Liu[1], J. Lee[1], T. Wiegelmann[2], J. Jing[1], Y. Xu[1], S. Wang[1], H. Wang[1]
[1]New Jersey Institute of Technology, [2]Max Planck Institut fur Sonnensystemforschung (MPS), Germany.
3:05 PM - 3:20 PM

A rapid and persistent change of the photospheric magnetic field co-temporal with the impulsive phase of solar flare emissions has been recognized as an important element of the flare process from both observational and theoretical points of view. Using the state-of-the-art photospheric vector magnetograms acquired by HMI and Hinode, we have studied such a change associated with the 2011 February 13 M6.6 flare in NOAA AR 11158. Our aim is not only to identify the field change but also to understand it in the context of magnetic reconnection involved with the flare. In our analysis, (1) the rapid change is detected in a compact region lying at the central neutral line, where the mean horizontal field strength increased significantly by 28% in 30 minutes. The field also becomes more sheared and inclined to the surface. (2) Sunspot umbrae with opposite polarity lying on the two sides of the compact region experienced sudden perturbations, moving in opposite directions at an apparent velocity of 3 km/s against the long-term evolution. (3) The field variation induces a downward Lorentz-force change acting on the compact region and two opposite horizontal components of the Lorentz-force change consistent with the sunspot motions. (4) Four conspicuous UV flare kernels appear at the event onset and are linked to ribbon-like hard X-ray emissions in the impulsive phase. The compact region lies between the central two kernels that are co-spatial with the central feet of the sigmoid according to the nonlinear force-free field (NLFFF) model. (5) The NLFFF model further shows that strong coronal currents are concentrated immediately above the compact region and undergo apparent downward collapse after the sigmoid eruption. These results are discussed in favor of both the tether-cutting reconnection producing the flare and the ensuing implosion (collapse) of the coronal field resulting from the energy release.

516.06 – **The Effect of Magnetic Topology on the Escape of Flare-accelerated Particles**

Sophie Masson[1], S. K. Antiochos[1], C. R. DeVore[2]
[1]NASA/GSFC, [2]NRL.
3:20 PM - 3:35 PM

Magnetic reconnection in the solar atmosphere is believed to be the driver of most solar active phenomena. Therefore, the structure and dynamics of the coronal magnetic field are central to understanding solar and heliospheric activity. Important heliospheric manifestations of intense energy release linked to solar activity include the impact at the Earth of energetic particles accelerated during solar eruptions. Observationally, the magnetic configuration of active regions, where solar eruptions occur, agrees well with the standard model of eruption, consisting of a flare and a coronal mass ejection (CME). According to the standard model, particles accelerated at the flare reconnection site should remain trapped in the CME. However, flare-accelerated particles frequently reach the Earth long before the CME does.

We present a new model that may lead to injection of energetic particles onto open interplanetary magnetic flux tubes. Our model is based on results of 2.5D MHD simulations of a large-scale coronal null-point topology with the outer spine opened to interplanetary space by an isothermal solar wind. The simulations are performed with the Adaptively Refined Mhd Solver (ARMS). We describe the multiple reconnections that occur during the evolution of the event, and show how they lead to the release of flare accelerated particles onto open field lines. We discuss the implications of our results for CME/flare models and for observations.

This work was supported, in part, by the NASA TR&T and SR&T Programs.

517 – ALMA Early Science Results & Opportunities

Special Session – Ballroom B, Dena'ina Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

At the Atacama Large Millimeter/submillimeter Array (ALMA) Special Session in Austin this January, Cycle 0 Early Science results will be presented from the first months of science operations. This Special Session, for the Anchorage AAS meeting, will report scientific results from most of the 9 month Cycle 0 Early Science program (30 September 2011 - 30 June 2012). During this period, ALMA sensitivity, image fidelity, and resolution will greatly improve compared to existing facilities at wavelengths from 0.4 to 3.6 mm (720 - 84 GHz), enabling transformative science across many fields of astrophysics.

The ALMA Cycle 0 Early Science Call for Proposals resulted in an exceptional over-subscription rate of 9:1. A diverse set of 112 high priority programs from scientists around the globe was granted observing time based on scientific merit as judged by an international review panel. North American PIs are leading 38 of these programs, with targets from Ioâ€™s atmosphere to high-z quasar hosts.

This Special Session will describe highlights from the North American ALMA Early Science observing programs and will be the first public presentation of ALMA science results obtained by the general community. After an overview of Early Science capabilities and opportunities, users from the North American community will present first science results on topics including the Solar System, planet-forming disks, molecular clouds, star formation, and high-z galaxies. We will solicit contributed oral presentations for ~ 50% of this Special Session.

The timing for this Special Session is particularly advantageous for the community in that it coincides with completion of the first ALMA Early Science cycle, and precedes a major international ALMA science conference being planned for October 2012 in Chile. This Special Session will provide an excellent and timely opportunity for AAS members to discuss the first ALMA science results and plan for future opportunities.

517.01 – **ALMA in Early Science (Cycles 0 and 1)**

Kartik Sheth[1]
[1]NRAO.
2:00 PM - 2:15 PM

ALMA's initial PI-driven science campaign ("Cycle 0") is now well underway and the deadline for the next round of Early Science ("Cycle 1") is this summer. Cycle 0 has already produced exciting results and ALMA has carried out an exciting Science Verification program. I will give an update on ALMA construction and operations and show early science highlights. I will review the capabilities available to the community in ALMA Cycle 1, which include and expanded number of antennas, increased correlator flexibility, and sensitivity to extended structure thanks to the inclusion of the ACA.

517.02 – **The Dynamics of Massive Starless Cores**

Jonathan Tan[1], P. Caselli[2], F. Fontani[3], S. Kong[1], M. J. Butler[1]
[1]Univ. of Florida, [2]University of Leeds, United Kingdom, [3]INAF - Osservatorio Astrofisico di Arcetri, Italy.
2:15 PM - 2:35 PM

Progress towards resolving a decade-long debate about how massive stars form can be made by determining if massive starless cores exist in a state of near virial

equilibrium. These are the initial conditions invoked by the Core Accretion model of McKee & Tan (2003). Alternatively, the Competitive Accretion model of Bonnell et al. (2001) requires sub-virial conditions. We have identified 4 prime examples of massive (~50 Msun) cores from mid-infrared (MIR) extinction mapping (Butler & Tan 2009, 2012) of Infrared Dark Clouds. We have found spectacularly high deuterated fractions of N_2H+ of ~0.5 in these objects with the IRAM 30m telescope (Fontani et al. 2011). Thus N_2D+ is expected to be an excellent tracer of the kinematics of these cold, dark cores, where most other molecular tracers are thought to be depleted from the gas phase. We report on ALMA Cycle 0 Compact Configuration Band 6 observations of these 4 cores that probe the N_2D+(3-2) line on scales from 9" down to 2.3", well-matched to the structures we see in MIR extinction and discuss their implications for massive star formation theories.

517.03 – **ALMA's View of Molecular Gas in 30 Doradus**

Remy Indebetouw[1], C. Brogan[2], ALMA 30 Doradus Cycle 0 Team
[1]*Univ. of Virginia,* [2]*NRAO.*
2:35 PM - 2:55 PM

30 Doradus is the nearest super-star cluster, and an ideal laboratory in which to study the effects of vigorous star formation on molecular gas in galaxies. We present observations of the northern molecular cloud in 30 Doradus, showcasing the power of ALMA, even in early science, to understand detailed physical conditions in extragalactic multiphase interstellar media. We image the cloud in the most commonly used extragalactic dense gas tracers including HCN, HCO+, CS, and CO. We study in detail the properties of dense starless and starforming clumps and cores in the cloud, and conditions in the interclump medium. In combination with Spitzer, Herschel, and other data, we can obtain a highly detailed picture of physical conditions in a real starburst PDR at reduced metallicity for the first time. These detailed studies are important to inform the interpretation of many ALMA observations of PDRs and molecular gas in more distant galaxies.

517.04 – **Probing the Molecular Outflows of the Coldest Known Object in the Universe: The Boomerang Nebula**

Raghvendra Sahai[1], W. Vlemmings[1], L. A. Nyman[1], P. Huggins[1]
[1]*Caltech.*
2:55 PM - 3:15 PM

The Boomerang Nebula is the coldest known object in the Universe, and an extreme member of the class of Pre-Planetary Nebulae, objects which represent a short-lived transitional phase between the AGB and Planetary Nebula evolutionary stages. The Boomerang's estimated prodigious mass-loss rate (0.001 solar masses/year) and low-luminosity (300 Lsun)

lack an explanation in terms of current paradigms for dusty mass-loss and standard evolutionary theory of intermediate-mass stars. Single-dish CO J=1-0 observations (with a 45 arcsec beam) show that the high-speed outflow in this object has cooled to a temperature significantly below the temperature of the cosmic background radiation. We report on our high-resolution ALMA mapping of the CO lines in this ultra-cold nebula to determine the origin of these extreme conditions and robustly confirm current estimates of the fundamental physical properties of its ultra-cold outflow.

517.05 – **Empirical Far Infrared Spectral Templates for High-z Galaxies**

Nicholas Scoville[1], N. Lee[2], E. LeFloch[3], D. Sanders[2]
[1]*Caltech,* [2]*IFA,* [3]*CEA, France.*
3:15 PM - 3:30 PM

Using infrared data in the COSMOS survey from Herschel (PACS and SPIRE) and Spitzer (MIPS and IRAC) we derive empirical SEDs for the far infrared emission based on samples of over 3000 galaxies at z = 0.1 to 4. These SEDs vary systematically with LIR. These SEDs are used for ALMA cycle 0 observations of the dust continuum in 120 galaxies out to z = 2 to estimate the ISM contents as a function of cosmic time.

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518 – Polaris: Mysteries of the North Star

Special Session – Ballroom C, Dena'ina Center – 6/14/2012 2:00:00 PM to 6/14/2012 3:30:00 PM

Polaris (The North Star) is the best known star in the Northern Sky. It belongs to the rarest class of stars: those that have not only aided our understanding of the Universe, but have in fact aided the very progress of humankind, literally helping us find our place on this world. According to Virginia Trimble "Some stars are born great, some achieve greatness while others have greatness thrust upon them". Polaris, as the North Star, had greatness thrust upon it several hundred years ago when precession brought it close to the North Celestial Pole. Since that time, Polaris (alpha Ursae Minoris) serves as an important navigational reference point. Moreover, because of its brightness and special place in the sky, Polaris is frequently alluded to in literature (e.g. Shakespeare's Juluis Casear - as constant as the North Star...) and often plays important roles in legends and myths. For example, in Inuit sky lore Polaris is known as Nuuttuittuq - "the star that never moves". But Polaris, as the nearest Classical Cepheid (and also member of a multiple star system) is astrophysically important and interesting in its own right since its physical properties can be precisely determined. For example, its distance provides a luminosity, pulsation mode and calibration for the Leavitt Law (Period-Luminosity relation). However, Polaris is full of surprises and mysteries. Over the last century Polaris has undergone rapid and large changes in its pulsation period (increasing at over 4 sec/yr.) and decreasing light and radial velocity amplitudes. During the early 1990s, Polaris nearly stopped pulsating and thus almost ceased being a Cepheid! More recently (and surprisingly) Polaris, and other Cepheids, have been found to have significant mass loss, and to even undergo X-ray and FUV-line emission variability in phase with their pulsations. This Session will highlight Polaris' place in history, and in the field of astronomy, and will also focus on the important role it now plays in the broader understanding of Cepheid structure and evolution.

518.01 – **Place in History and Astrophysics as the Pole Star and the Nearest Cepheid**

Edward F. Guinan[1]
[1]*Villanova Univ..*
2:00 PM - 2:10 PM

Over ten centuries ago years, precession moved the Earth's North Celestial Pole (NCP) near the direction of alpha Ursae Minoris - now known as Polaris. Since that time Polaris has served as an important navigation star. By 2100 (at closest approach) Polaris moves within ~0.5 deg of the NCP. Because of its brightness (~2nd mag) and fixed place in the sky, Polaris is frequently referenced in literature, folklore, and pop culture. For example, in the Arctic, Polaris is known to the Inuit (among other names) as *Nuuttuittuq* ("never moves"), while the Yup'ik Eskimo refer to Polaris as *Agyarrlak* ("major star"). But Polaris, as the nearest Classical Cepheid (and also member of a multiple star system) is astrophysically important and interesting in its own right. Primarily this is because Polaris' physical properties can be precisely determined. Its distance provides a luminosity, pulsation mode and calibration for the Leavitt Law (Period-Luminosity relation). But, Polaris has been found to be full of surprises and puzzles. Over the last century Polaris has been undergoing rapid, large changes in its pulsation period (increasing at over 4 sec/yr.) as well as in its light and radial velocity variations. Noteworthy, during the early-1990s, Polaris nearly stopped pulsating and thus almost ceased being a Cepheid! Surprisingly Polaris (and other Cepheids) recently have been discovered to have significant mass-loss, and to display X-ray and FUV-line emission variations in phase with their pulsations. In this introductory talk Polaris' place in history and in the field of astronomy will be briefly discussed along with the important role it plays in the broader understanding of Cepheid structure and evolution.

This research is, in part, supported by NASA Grants HST-GO11726.01 and NNX08AX37G, which we gratefully acknowledge.

518.02 – **The Basics: Fundamental Properties - Polaris as a Classical Cepheid**

Nancy Remage Evans[1]
[1]*SAO.*
2:10 PM - 2:20 PM

Polaris is the nearest Classical Cepheid and as such provides a good example of many directly derived characteristics. The distance provides a luminosity and pulsation mode, calibration for the Cepheid Leavitt law (Period-Luminosity relation). It is a member of a multiple star system requiring a number of techniques to derive parameters for the system members. Finally, the mass of the supergiant can be derived from a combination of ground-based and satellite observations.

518.03 – **Polaris: Evolutionary (and Other !) Period Changes and Clues to its Nature**

David G. Turner[1]
[1]*Saint Mary's Univ., Canada.*
2:20 PM - 2:30 PM

O-C data for the Cepheid Polaris derived from its brightness and radial velocity variations are consistent with a regular period increase of 4.5 seconds per year during the past two centuries, with the exception of a unique hiatus circa 1965 when the pulsation period underwent a brief decrease that is difficult to explain without invoking assimilation of a substellar companion. The 30-year cycle of the Polaris Aa subsystem is evident both in the star’s systemic radial velocity variations and observed times of light maximum, the latter of which display light travel time effects larger than expected. Arguments for overtone versus fundamental mode pulsation in the star appear to favor Polaris as an overtone pulsator, which is supported by its potential cluster membership, yet are currently unable to explain all of its observational characteristics: small amplitude in conjunction with location near the center of the instability strip, rapid period increase, X-ray emission, etc. Perhaps future or ongoing space observations will shed light on the puzzle.

518.04 – **The HST/FGS Cepheid Period-Luminosity Calibration and Subsequent Uses**

G. Fritz Benedict[1], B. E. McArthur[1]

[1]*Univ. of Texas, Austin.*
2:30 PM - 2:40 PM

In 2007 we published new absolute trigonometric parallaxes for ten Galactic Cepheid variable stars with an average parallax error of 8%. With these parallaxes we computed absolute magnitudes in V, I, K, and Wesenheit W(VI) bandpasses, corrected for interstellar extinction and Lutz-Kelker bias. We constructed Period-Luminosity relations (Leavitt Laws) for these ten Galactic Cepheids and obtained zero-point errors of 0.03 magnitude. We briefly review how this was done and summarize recent applications of our calibration.

518.05 – **Mass Loss in Cepheids: Observational Evidence from IR and Radio Data**

Massimo Marengo[1]

[1]*Iowa State University.*
2:40 PM - 2:50 PM

The recent detection of infrared shells around Polaris and other Cepheids has rekindled the interest of astronomers in Cepheid mass loss. High mass loss rate has been invoked to explain the so-called "Cepheids' mass discrepancy" as well as the large and rapid period change observed in Polaris and other Cepheids. Its existence, however, has been surprisingly difficult to demonstrate unequivocally. I will briefly review the latest observational evidence, at radio and infrared wavelength, of high mass loss rates in Cepheid stars. I will then present the first direct measurement of a Cepheid's stellar wind.

518.06 – **The Life and Times of the North Star: What Evolution Models Are Saying about Polaris and Other Cepheids**

Hilding Neilson[1]

[1]*University of Bonn, Germany.*
2:50 PM - 3:00 PM

Building on measurements of the fundamental properties and rate of period change of Polaris, we can constrain stellar evolution models to an almost unprecedented degree. From a dense grid of stellar evolution models, we predict theoretical rates of period change and find they are inconsistent with the observed rate for the given effective temperature and luminosity. This difference is resolved if Polaris is losing mass at a significant rate of 10^{-6} solar masses per year, suggesting a direct indicator of Cepheid mass loss. If the significant mass loss of Polaris is representative of Cepheids as a whole, then Cepheid mass loss will help resolve the long-standing Cepheid mass discrepancy and constrain physical processes in stellar evolution models.

518.07 – **Shocking new Discoveries from Polaris and other Cepheids**

Scott G. Engle[1]

[1]*Villanova Univ..*
3:00 PM - 3:10 PM

In our attempts to try and “shed new light” on Polaris and other Cepheids, we expanded our study into the hitherto underutilized (for Cepheids) X-ray and FUV wavelength regimes. In doing so, we realized that the current generation of satellites and instruments could answer an important question: Just what are the atmospheres of Cepheids like? The 1980s IUE studies of Schmidt & Parsons gave hints that perhaps some Cepheids could show emissions from 10^5 K plasmas, but the detector (and the results) were heavily affected by scattered light contamination. By utilizing HST-COS, we’ve secured UV spectra of selected bright Cepheids far beyond what IUE led us to suspect. The data are rich with strong FUV emission lines from ionized plasmas within the Cepheid atmospheres, and show interesting atmospheric motions, pointing to possible shock formation caused by the stellar pulsations. X-ray data from XMM-Newton and Chandra have also been secured, indicating $\sim 10^6$ K plasmas are also present in Cepheids. So far from partial data, these X-ray and FUV emission appear to be phased with the pulsations of the stars. The combination of X-ray and UV data tells us a great deal about the heating mechanism at work.

This research is supported by the following NASA grants: XMM-Newton Grant No. NNX08AX347G and HST Grants HST-GO-12302 and HST-GO-11726. We gratefully acknowledge the support from these grants and the scientists and engineers of these missions.

519 – Mix One-Part Astronomy Education Research with One-Part General Education Astronomy Course and You Get a Very Potent Science Literacy Transformation Cocktail

Invited Session – Ballroom B, Dena'ina Center – 6/14/2012 3:40:00 PM to 6/14/2012 4:30:00 PM

519.01 – **Mix One-Part Astronomy Education Research with One-Part General Education Astronomy Course and You Get a Very Potent Science Literacy Transformation Cocktail**

Edward E. Prather[1]

[1]*CAE/University of Arizona.*
3:40 AM - 4:30 PM

Are you doing the job that our society needs you to do? Are you successful at it? How do you know? Over the past decade we have worked closely with hundreds of college instructors, postdocs, graduate students, and undergrads in collaborative research projects designed to help us understand fundamental issues of teaching and learning in college-level general education astronomy and space science courses. The results from these multi-institutional research collaborations have been used to transform classrooms all over the country. We are creating learning environments that significantly improve the science literacies and engagements in STEM of the hundreds of thousands of students taking these courses each year. By moving students along the continuum from non-science majors, to peer instructors, to researchers and curriculum developers, to STEM and STEM education degree seeking students, we are creating the next generation’s “Ambassadors of Science.”

520 – AIP Gemant Award: Tycho to Kepler: Four Centuries and More of Astronomy and the Media

Invited Session – Ballroom B, Dena'ina Center – 6/14/2012 4:30:00 PM to 6/14/2012 5:20:00 PM

520.01 – **Tycho to Kepler: Four Centuries and More of Astronomy and the Media**

Stephen P. Maran[1]

[1]*American Astronomical Society.*
4:30 PM - 5:20 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.

521 – The Sun & Solar Topics

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

521.01 – **Effects Of Langmuir Waves On Flare-accelerated Electrons In The Inhomogeneous Coronal Plasma**

Heather Ratcliffe[1], E. P. Kontar[1]

[1]*University of Glasgow, United Kingdom.*

9:00 AM - 2:00 PM

Solar flares accelerate beams of electrons, the number and energy of which may be estimated from the hard X-rays (HXR) they emit. The standard collisional thick target model assumes the emitting electrons are modified only by collisions. However, the electron beam produces Langmuir waves as it propagates through the inhomogeneous solar corona. The interaction between these Langmuir waves and density fluctuations, in the limit of fluctuations with spatial scale much larger than the Langmuir wavelength, can be described by a diffusion equation. We evaluate the diffusion coefficient for various spectra of density fluctuations, considering both those due to waves with a defined dispersion relation, and those with arbitrary frequency and wavenumber spectra. Simulations for the case of a 1-dimensional electron beam generating Langmuir waves which then diffuse, showed an acceleration effect on the electrons, increasing the number at high energies in the time-integrated distribution. The magnitude and form of the diffusion coefficient may therefore be important in the interpretation of HXR observations of non-thermal electrons, as the increased number of electrons at high energies could lead to an overestimate of the total number and energy of the originally accelerated electrons.

521.02 – **Diagnosing the Prominence-Cavity Connection**

Donald Schmit[1], S. Gibson[2]

[1]*University of Colorado-Boulder,* [2]*High Altitude Observatory.*

9:00 AM - 2:00 PM

Prominences are regions of cool, dense plasma which are suspended above the solar limb within the much hotter and more rarefied solar corona. The coronal environment surrounding the prominence is often observed as a elliptical region of reduced density (compared to the ambient corona) known as a cavity. To date, the cavity has been a neglected constraint on the prominence system. In this research, I probe the magnetic structural connection between the cavity and prominence and the potential role the cavity plays in the mass and energy balance of the prominence. Observationally, I use the Hinode/EIS and SDO/AIA datasets to extract dynamic substructure from the cavity. The temperature-sensitivities of these data are used to diagnose the interaction of plasma in the prominence and in the surrounding corona.These observational dynamics present a viable constraint on prominence models in two ways. Structurally, the morphology of the extract substructure can be compared to the 3D models of prominence support. Energetically, the spatial and temporal signature of EUV dynamics can be compared to the thermal non-equilibrium model for prominence mass supply. This joint approach systematically addresses the two largest questions in prominence research: how is the prominence mass supported and where does it come from.

521.03 – **Detection of the Horizontal Divergent Flow (HDF) as a Precursor of Sunspot Emergence**

Shin Toriumi[1], K. Hayashi[2], T. Yokoyama[1]

[1]*University of Tokyo, Japan,* [2]*Stanford University.*

9:00 AM - 2:00 PM

The SDO/HMI data reveals that a horizontal divergent flow (HDF) appears about 100 min before the sunspot emergence. It is widely accepted that solar active regions including sunspots are the consequence of the rising magnetic flux from the convection zone (flux emergence). In this study we report the detection of the HDF in the photosphere, prior to the start of flux emergence. The HDF was previously reported in our numerical study; the plasma on the top of emerging flux escapes horizontally around the photosphere before the flux reaches the surface. For the observational study, we use SDO/HMI Dopplergrams and magnetograms of NOAA AR 11081 on June 11, 2010. We investigate the differences of each (Doppler and magnetic) profile of this region from that of the quiet Sun, and define the HDF appearance and the flux emergence as the times when each difference exceeds one standard deviation level (one-sigma) of the reference quiet-Sun profile. As a result, it is found that HDF occurs about 100 min before the associated flux emergence. Also, the horizontal speed of the outflow is measured to be 0.6-1.5 km/s, up to 2.3 km/s. One importance of observing HDF may be the possibility to predict the sunspot emergence that occurs in several hours.

521.04 – **Evidence for Impulsive Heating of Active Region Coronal Loops**

Jeffrey Reep[1], S. Bradshaw[1]

[1]*Rice University.*

9:00 AM - 2:00 PM

We present observational and numerical evidence supporting the theory of impulsive heating of the solar corona. We have run numerical simulations solving the hydrodynamic equations for plasma confined to a magnetic flux tube, for both the cases of steady and impulsive heating. We find that steady heating cannot explain the observed amount of low-temperature plasma in active regions on the sun. The results for impulsive heating closely match those of observations. The ratio of heating time to cooling time dominates the observed temperature distribution of the plasma. We have also identified an observational bias in calculating intensities of spectral lines, which causes an under-estimation of low-temperature plasma. We predict Doppler shifts that are in agreement with observations, and which may diagnose the strength of heating. We conclude that impulsive heating of active region coronal loops is more likely than steady heating.

521.05 – **Solar Flare Observations of the EUV Continua**

Ryan O. Milligan[1], P. Chamberlin[2], H. Hudson[3], T. Woods[4], M. Mathioudakis[1], L. Fletcher[5], A. Kowalski[6], F. Keenan[1]

[1]*QUB, United Kingdom,* [2]*NASA/GSFC,* [3]*Space Science Lab,* [4]*LASP,* [5]*University of Glasgow, United Kingdom,* [6]*University of Washington.*

9:00 AM - 2:00 PM

Recent solar flare simulations suggest that the energy deposited in the chromosphere by nonthermal electrons during a flare's impulsive phase is re-emitted in the form of recombination (free-bound) continua, in particular, the Lyman, Balmer, and Paschen continua of hydrogen, and the He I and He II continua (Allred et al. 2005). However, definitive observations of free-bound emission during solar flares have been scarce in recent years as many modern, space-based instruments do not have the required sensitivity, wavelength coverage, or duty cycle. With the launch of SDO, these observations are now routinely available thanks to the EUV Variability Experiment (EVE) instrument. Here we present unambiguous, spectrally and temporally resolved detections of enhanced free-free and free-bound continua during the first X-class solar flare of Solar Cycle 24. While we find that the flare energy in the EVE spectral range amounts to at most a few percent of the total flare energy, these findings highlight the capability of EVE in giving us the first comprehensive look at these diagnostically important continuum components.

521.06 – **Stereo Observations Of Fast Magnetosonic Waves In The Extended Corona**

Ryun Young Kwon[1], J. M. Davila[2], L. Ofman[1]

[1]*Catholic University of America/NASA Goddard Space Flight Center,* [2]*NASA Goddard Space Flight Center.*

9:00 AM - 2:00 PM

Here, we present fast magnetosonic waves propagating across solar radial magnetic fields. STEREO COR1 and EUVI observations showed coronal disturbances associated with flares/CMEs and they propagate in the low solar corona in the form of EIT waves and in the high solar corona (above 1.5 Rs) in the form of density compressions along radial magnetic field lines above EIT wave fronts. It turns out that the coronal disturbances pass through streamers which contain a magnetic separatrix. The wave energy appears to be trapped by the streamers and this leads to stationary fronts at the footpoints of the streamers. Our results suggest that the coronal disturbances associated with flares/CMEs are fast magnetosonic waves propagating with local fast magnetosonic speeds and passing through magnetic separatrices. Moreover, we conclude that EIT waves are ‘real’ fast magnetosonic waves. The speeds of the coronal disturbances are 475 ± 14, 926 ± 19, 1217 ± 24, 1734 ± 48, and 1928 ± 42 km/s at 1.0, 1.6, 2.0, 2.5, and 3.0 Rs, respectively. Using coronal seismology, we estimated magnetic field strengths corresponding to these speeds at the heights and they are 1.81 ± 0.06, 0.98 ± 0.02, 0.70 ± 0.01, 0.55 ± 0.02, and 0.39 ± 0.01 G, respectively.

521.07 – **Some Like it Hot: the Trajectory of Sungrazing Comet C/2011 W3 (Lovejoy) in the Solar Neighborhood.**

Pascal Saint-Hilaire[1], P. W. Chodas[2], K. Battams[3], T. D. Tarbell[4], R. A. Shine[4], W. Liu[5], W. T. Thompson[6], Comet Lovejoy Collaboration Team

[1]*Space Sciences Laboratory, University of California, Berkeley,* [2]*Jet Propulsion Laboratory,* [3]*Naval Research Laboratory,* [4]*Lockheed Martin Solar and Astrophysics Laboratory,* [5]*Stanford-Lockheed Institute for Space Research,* [6]*Adnet Systems, Inc., NASA Goddard Space Flight Center.*

9:00 AM - 2:00 PM

Sungrazing comet Lovejoy (C/2011 W3) was a recent spectacle in the sky, observed from the ground and by a host of space-based instruments, including several solar observatories. It is the first sungrazing comet in recent memory to have survived perihelion (q~1.2 Rs). It is only the second sungrazer to have been observed in the Sun's low corona in the extreme ultra-violet (EUV), where a plethora of EUV observations were obtained by the SDO and STEREO spacecraft. Such an occurrence can be used to probe the solar corona and test our understanding of plasma and cometary physics. In this work, we use the best orbit elements currently available to plot the path of the comet's nucleus on solar EUV images from SDO/AIA, both STEREO/EUVIs, and yellow continuum (near the Na D lines) images from Hinode/SOT. We compare the predicted positions and timing of the comet's nucleus to the latter, while the SDO and STEREO EUV observations are used to estimate the distance at which the EUV tail appears behind the comet's nucleus.

521.08 – **Propagation Characteristics of CMEs Associated Magnetic Clouds and Ejecta**

Roksoon Kim[1], N. Gopalswamy[1], K. Cho[1], Y. Moon[2], S. Yashiro[1]

[1]*NASA/GSFC,* [2]*Kyunghee University, Korea, Republic of.*

9:00 AM - 2:00 PM

We have investigated the characteristics of magnetic cloud (MC) and ejecta (EJ) associated coronal mass ejections (CMEs) based on the assumption that all CMEs have a flux rope structure. For this, we used 54 CMEs and their interplanetary counter parts (interplanetary CMEs: ICMEs) that constitute the list of events used by the NASA/LWS Coordinated Data Analysis Workshop (CDAW) on CME flux ropes. We considered the location, angular width, speed, and direction parameter, D, that quantifies the propagation direction of a CME. For the 54 CDAW events, we found several properties of the CMEs as follows: (1) the average value of D for the 23 MCs (0.62) is larger than that for the 31 EJs (0.49), which indicates that the MC-associated CMEs propagate more directly to the Earth than the EJ-associated CMEs; (2) comparison between the direction parameter and the source location shows that the majority of the MC-associated CMEs are ejected along the radial

direction, while many of the EJ-associated CMEs are ejected non-radially; (3) the mean speed of MC-associated CMEs (946 km/s) is faster than that of EJ-associated CMEs (771 km/s). For seven very fast CMEs (> 1500 km/s), all CMEs with large D (> 0.4) are associated with MCs and the CMEs with small D are associated with EJs. On the basis of these results, we suggest that the CME trajectory essentially decides the observed ICME structure.

521.09 – **Waves and Flares**

Aleksandra Andic[1], R. McAteer[1], J. Jackiewicz[1], L. Boucheron[1], H. Cao[1], B. McNamara[1]

[1]*New Mexico State University.*

9:00 AM - 2:00 PM

It has been demonstrated that movement of the flux tube can cause oscillations (Andic et al. 2010). In this work we present preliminary research that shows what happens with the oscillations before, during, and after magnetic field reconfigurations caused by explosive events. We detect oscillations at locations where the magnetic field touches the photosphere. However, we plan to analyze a larger statistical sample of flaring active region to better quantify the relation between these oscillations and movement of flux tubes caused by disturbances in the magnetic field.

521.11 – **Structure and Dynamics of Quiescent Prominence Eruptions**

Muzhou Lu[1], Y. Su[2], A. Adriaan van Ballegooijen[2]

[1]*Williams College,* [2]*Harvard-Smithsonian Center for Astrophysics.*

9:00 AM - 2:00 PM

We present a survey on the fine structure and dynamics of quiescent prominence eruptions observed both on the disk and at the limb. We have identified 45 quiescent prominence eruptions by looking at the SDO (Solar Dynamics Observatory)/AIA (Atmospheric Imaging Assembly) daily movies from April to June in 2011. Among these events, there are 24 symmetric eruptions (coherent loop-like eruptions) and 21 asymmetric eruptions (one footpoint lifts off) as shown by AIA and STEREO/EUVI observations. Vertical filament threads are identified in 10 out of the 45 events, while horizontal threads are observed in almost all eruptions. We find 23 events with twisting/untwisting motions. For 14 selected limb events, we carry out a detailed study of the eruption dynamics using AIA observations at 304 Å. We find that the initial heights of these erupting prominences are located around 50-110 Mm above the limb. The eruptions start from a speed of less than 5 km/s, then increase to several tens km/s in the AIA field of view. The maximum speed of these events is 50 km/s. The acceleration plots show a positive acceleration in the range of 0 to 20 m/s^2. No significant difference is identified in the dynamics of the symmetric and asymmetric eruptions. Acknowledgments. This project is supported by the NASA contract SP02H1701R from LMSAL to Smithsonian Astrophysical Observatory (SAO). M. Lu is supported under the NSF-REU solar physics program at SAO, grant number ATM-0851866.

521.12 – **Solar Hard X-ray Observations with NuSTAR**

Andrew Marsh[1], D. M. Smith[1], S. Krucker[2], H. S. Hudson[2], G. J. Hurford[2], S. M. White[3], R. A. Mewaldt[4], F. A. Harrison[4], B. W. Grefenstette[4], D. Stern[5]

[1]*UC Santa Cruz,* [2]*UC Berkeley,* [3]*AFRL,* [4]*Caltech,* [5]*JPL.*

9:00 AM - 2:00 PM

High-sensitivity imaging of coronal hard X-rays allows detection of freshly accelerated nonthermal electrons at the acceleration site. A few such observations have been made with Yohkoh and RHESSI, but a leap in sensitivity could help pin down the time, place, and manner of reconnection. Around the time of this meeting, the Nuclear Spectroscopic Telescope ARray (NuSTAR), a NASA Small Explorer for high energy astrophysics that uses grazing-incidence optics to focus X-rays up to 80 keV, will be launched. Three weeks will be dedicated to solar observing during the baseline two-year mission. NuSTAR will be 200 times more sensitive than RHESSI in the hard X-ray band. This will allow the following new observations, among others: 1) Extrapolation of the micro/nanoflare distribution by two orders of magnitude down in flux; 2) Search for hard X-rays from network nanoflares (soft X-ray bright points) and evaluation of their role in coronal heating; 3) Discovery of hard X-ray bremsstrahlung from the electron beams driving type III radio bursts, and measurement of their electron spectrum; 4) Hard X-ray studies of polar soft X-ray jets and impulsive solar energetic particle events at the edge of coronal holes; 5) Study of coronal bremsstrahlung from particles accelerated by coronal mass ejections as they are first launched; 6) Study of particles at the coronal reconnection site when flare footpoints and loops are occulted; 7) Search for weak high-temperature coronal plasmas in active regions that are not flaring; and 8) Search for hypothetical axion particles created in the solar core via the hard X-ray signal from their conversion to X-rays in the coronal magnetic field. NuSTAR will also serve as a pathfinder for a future dedicated space mission with enhanced capabilities, such as a satellite version of the FOXSI sounding rocket.

521.13 – **Temperature Structure of a Coronal Cavity and Streamer**

Therese A. Kucera[1], S. E. Gibson[2], D. J. Schmit[3], E. Landi[4], D. Tripathi[5]

[1]*NASA's GSFC,* [2]*NCAR/HAO,* [3]*University of Colorado,* [4]*University of Michigan,* [5]*Inter-University Centre for Astronomy and Astrophysics, India.*

9:00 AM - 2:00 PM

We analyze the temperature and EUV line emission of a coronal cavity and surrounding streamer in terms of a morphological forward model. We use a series of iron line ratios observed with the Hinode Extreme-ultraviolet Imaging Spectrograph (EIS) on 2007 Aug. 9 to constrain temperature as a function of altitude in a morphological forward model of the streamer and cavity. We also compare model prediction of the EIS EUV line intensities and polarized brightness (pB) data from the Mauna Loa Solar Observatory (MLSO) MK4. This work builds on earlier analysis using the same model to determine geometry of and density in the same cavity and streamer (Gibson et al. 2010 and Schmit and Gibson 2011). The fit to the data with altitude dependent temperature profiles indicates that both the streamer and cavity have temperatures in the range 1.4-1.7 MK. However, the cavity exhibits substantial substructure such that the altitude dependent temperature profile is not sufficient to completely model conditions in the cavity. This work is supported in part by the NASA SHP program

521.14 – **The Effect Of Phase-speed Filtering On Time-distance Analysis Of Meridional Flow In The Solar Convection Zone.**

Sudeepto Chakraborty[1], T. L. Duvall, Jr[2], T. Hartlep[1]

[1]*W. W. Hansen Experimental Physics Laboratory, Stanford University,* [2]*Solar Physics Laboratory, NASA Goddard Space Flight Center.*

9:00 AM - 2:00 PM

Meridional circulation in the solar convection zone is a key ingredient in flux-transport type models of the solar magnetic cycle. Time-distance helioseismology is a method that can be used to infer the meridional flow profile in the subsurface regions of the Sun from observations of the solar surface. In this work we use deep-focus time-distance techniques on simulation data to measure travel time differences due to meridional flows deep within the convection zone. In particular, we explore the effect of phase-speed filtering in potentially enhancing our ability to measure travel-time differences due to meridional flows throughout the convection zone.

521.15 – **Estimate of Energy Release In a Major Flare Using Coronal Loops Data**

Anna Malanushenko[1], C. J. Schrijver[2], M. L. DeRosa[2]

[1]*LMSAL/MSU,* [2]*LMSAL.*

9:00 AM - 2:00 PM

Coronal loops provide with valuable source of information about coronal magnetic field. In particular, they allow one to observe reconfiguration of the coronal magnetic field during eruptive episodes. The changes in the coronal field, as observed in X-rays and extreme ultraviolet, are often dramatic in even minor eruptions. Therefore, models of magnetic field which take coronal loops into account might provide for new insight at changes of the field during eruptions. We use coronal loops data (gathered from SDO/AIA images) along with the line-of-sight magnetograms (by SDO/HMI) to model magnetic field in AR 11158 before and after the so-called Valentine's Flare, an X-class flare in Feb 15, 2011. This is done using the recently developed Quasi Grad-Rubin algorithm (QGR), which allows a reconstruction of non-linear force-free field based on information about electric currents along a set of arbitrary tracks in the computational domain. Tests of QGR on solar-like fields demonstrate its ability to recover over 50% of the free energy, as well as the large-scale structure of currents and overall shape of field lines. We analyze model magnetic fields of AR 11158 before and after the flare, demonstrate their resemblance with the observed structure of coronal loops and analyze the changes in the structure of currents caused by the flare, and compare our results with existing studies of the same event.

521.16 – **Radiating Current Sheets in the Solar Chromosphere**

Michael L. Goodman[1], P. G. Judge[2]

[1]*West Virginia High Technology Consortium Foundation (MLG's work is supported by the National Science Foundation),* [2]*High Altitude Observatory, National Center for Atmospheric Research (NCAR - NCAR is sponsored by the National Science Foundation).*

9:00 AM - 2:00 PM

An MHD model of a Hydrogen plasma with flow, an energy equation, NLTE ionization and radiative cooling, and an Ohm's law with anisotropic electrical conduction and thermoelectric effects is used to self-consistently generate atmospheric layers over a 50 km height range. A subset of these solutions contain current sheets, and have properties similar to those of the lower and middle chromosphere. The magnetic field profiles are found to be close to Harris sheet profiles, with maximum field strengths ~ 25-150 G. The radiative flux F_R emitted by individual sheets is ~ 4.9 x 10^5 - 4.5 x 10^6 ergs-cm^{-2}-s^{-1}, to be compared with the observed chromospheric emission rate of ~ 10^7 ergs-cm^{-2}-s^{-1}. Essentially all emission is from regions with thicknesses ~ 0.5 - 13 km containing the neutral sheet. About half of F_R comes from sub-regions with thicknesses 10 times smaller. A resolution <~ 5-130 m is needed to resolve the properties of the sheets. The sheets have total H densities ~ 10^{13}-10^{15} cm^{-3}. The ionization fraction in the sheets is ~ 2-20 times larger, and the temperature is ~ 2000-3000 K higher than in the surrounding plasma. The Joule heating flux F_J exceeds F_R by ~ 4-34 %, the difference being balanced in the energy equation mainly by a negative compressive heating flux. Proton Pedersen current dissipation generates ~ 62-77 % of the positive contribution to F_J. The remainder of this contribution is due to electron current dissipation near the neutral sheet where the plasma is weakly magnetized. These solutions represent the first, first principles theoretical proof of the existence of radiating current sheets under chromospheric conditions. The existence of these solutions suggests the existence of sub-resolution, horizontal current sheets in the chromosphere that are sites of strong Joule heating driven radiative emission.

521.17 – **FISS Observations of Chromospheric Transient Brightenings associated with Canceling Magnetic Features**

Soyoung Park[1]

[1]*Korea Astronomy and Space Science Institute, Korea, Republic of.*

9:00 AM - 2:00 PM

Canceling magnetic features (CMFs) are likely to be a result of magnetic reconnection in the lower atmosphere. CMFs are often related with chromospheric phenomena such as brightening or jets. In order to observe the fine-scale and highly dynamical structures in the chromospheres, Fast Imaging Solar Spectrograph (FISS) was developed and installed at 1.6 m New Solar Telescope at Big Bear Solar Observatory. This FISS records spectral lines at two spectral bands in the chromosphere, the H-alpha and the Ca II 8542, simultaneously. Using the FISS data we have studied chromospheric brightenings associated with magnetic elements including CMFs. As a result, the chromospheric brightenings related with CMFs have stronger shock waves than one of other regions such as internetwork regions or unipolar magnetic elements.

521.18 – **The Sun Has A Short Memory: Turbulent Pumping Of Magnetic Flux Reduces Solar Cycle Memory And Precludes Long-term Predictions**

Dibyendu Nandy[1], B. B. Karak[2]

[1]Indian Institute of Science Education and Research, Kolkata, India, [2]Indian Institute of Science, India.

9:00 AM - 2:00 PM

Predicting the activity of the Sun is important because of its effect on space environmental conditions and climate. However, recent efforts to predict the amplitude of the solar cycle have resulted in diverging forecasts with no consensus. It is understood that the dynamical memory of the solar dynamo mechanism governs predictability and this memory is different for advection- and diffusion-dominated solar convection zones. By utilizing stochastically forced, kinematic dynamo simulations, we demonstrate that the inclusion of downward turbulent pumping of magnetic flux reduces the memory of both advection- and diffusion-dominated solar dynamos to only one cycle; stronger pumping degrades this memory further. We conclude that the dynamical memory of the solar cycle is short; reliable predictions for the maximum of solar activity can be made only at the preceding minimum which explains why early forecasts for the maximum of solar cycle 24 have widely diverged. Our analysis suggests that for more accurate predictions, sequential data assimilation would be necessary in forecasting models to account for the Sun's short memory.

521.19 – **Spectropolarimetry of a Limb Active Region and its Cool Coronal Structures**

Philip G. Judge[1], L. Kleint[1], R. Casini[1], T. Schad[2]

[1]HAO, NCAR, [2]Lunar and Planetary Lab, U. Arizona.

9:00 AM - 2:00 PM

During the SDO mission we have regularly used the IBIS and FIRS spectropolarimeters at the Dunn Solar Telescope to measure magnetic fields and plasma parameters from photosphere up to the coronal base. Here we analyze data of a region at and above the east limb (later named NOAA 11302) obtained on September 22nd 2011. The measurements show an erupting prominence, remarkably uniform cool plumes and some material seemingly draining into the active region along post-flare loops. The imaging Fabry-Perot instrument IBIS obtained 30 scans of intensity spectra (30s cadence) and 40 scans of Stokes parameters (90s cadence) in lines of Fe I 630 nm, Na I 596 nm, Ca II 852 nm and H-alpha 656 nm, with an angular resolution near 0.2", over a 40"x80" field of view. The FIRS slit was scanned across the solar image to obtain Stokes profiles including lines of Si I 1028.7 nm and He I 1083 nm. We obtained 3 FIRS scans covering a 90"x75" area with cadences of between half an hour and an hour simultaneously with IBIS, at a lower angular resolution. Simultaneous broad band Ca II K and G-band data were obtained with a cadence of 5s. We discuss the vector magnetic fields and plasma properties of NOAA 11302, with emphasis on cool plasma structures extending many Mm into the corona.

521.2 – **Observation of “Transmission” of an EUV Wave Through a Coronal Hole**

Oscar Olmedo[1], A. Vourlidas[1], J. Zhang[2], X. Cheng[3]

[1]Naval Research Laboratory, [2]George Mason University, [3]Nanjing University, China.

9:00 AM - 2:00 PM

We present for the first time what appears to be the “transmission” of an EUV wave through a coronal hole. Though this effect had not previously been observed, numerical simulations indicate that EUV waves can cross coronal holes. The EUV wave event studied in this work occurred on 2011 February 15 and was associated with an X class flare. It is seen that the part of the wave that crosses the coronal hole appears to accelerate relative to the part over the quiet Sun. This observation is fully consistent with the behavior of a fast-mode wave since the fast-mode speed will be higher in a coronal hole (due to its reduced plasma density) than in the quiet Sun at a given height. These observations are hard to reconcile with a pure pseudo-wave interpretation of EUV waves. Our findings indicate that we accept either all EUV waves as fast-mode waves or the hybrid interpretation of EUV waves where the coronal mass ejections outer envelope, observed as a pseudo-wave, triggers a fast-mode wave seen later on in the event. In the latter scenario the EUV wave should look to propagate continuously as the coronal mass ejection leaves behind a fast-mode wave in its wake. And it is this fast-mode wave that crosses the coronal hole.

521.21 – **Daily Coronal MHD Simulation Using HMI Near-Real-Time Magnetograms**

Keiji Hayashi[1], HMI team

[1]Stanford University.

9:00 AM - 2:00 PM

SDO/HMI is making full-disk line-of-sight magnetogram measurements with a cadence of 45 seconds. The HMI analysis pipeline regularly generates two types of synoptic map of the solar surface magnetic field. Definitive calibrated data maps are created every Carrington Rotation, about every 27 days and a preliminary synoptic map is updated on a near-real-time basis. As an application of the near-real-time data, we have been running a daily MHD simulation of the global solar corona using the photospheric map as the boundary condition (http://hmi.stanford.edu/MHD). The daily MHD model assumes a polytropic gas with the specific heat ratio of 1.05, and the simulation is conducted in a 4-pi spherical grid system with latitudinal and longitudinal grid sizes of pi/64. The output available at hmi.stanford.edu/MHD includes the three-dimensional volume data, the shape of the open-field regions corresponding to the coronal holes, and the LoS-integration of the coronal density mimicking coronagraph observations. For validation, we compare the results of the low-resolution daily MHD simulation and the high-resolution PFSS calculation with SDO/AIA and SOHO/C2 and C3 image data. In the future the simulation region will be extended to 1 AU, and models of coronal heating and acceleration will be applied to allow a timely prediction of solar wind at the Earth for space weather purposes.

522 – Instrumentation, Computation and Laboratory Astrophysics

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

522.01 – **Current Status Of Our Work On Improved Uv Coatings**

Matthew N. Beasley[1], S. Nikzad[2], H. Greer[2]

[1]University of Colorado at Boulder, CASA, [2]Jet Propulsion Laboratory.

9:00 AM - 2:00 PM

Current FUV instrumentation is seriously compromised by poor reflectivity. The best existing coatings for the 90 - 115 nm range are SiC (30% reflectivity across the band) and LiF/Aluminum (60% reflectivity from 100 nm to 115 nm). An improved coating therefore would enable the production of vastly more sensitive instruments in the 90 - 200 nm range. An additional goal in the development of an alternate FUV coating is to overcome the well-documented hygroscopic behaviors of LiF coatings, which currently impose handling concerns that in turn drive cost and schedule. The coatings we will develop in this effort must also function well through the conventional silicon-based detector bandpass (200 nm to 1100 nm). By ensuring that these new coatings are usable at many wavelengths, we will make it possible to incorporate ultraviolet instruments into future large missions without compromising the science capability of other instruments or increasing cost and risk due to handling issues. We present the current status of our project and future work.

522.02 – **First Light for MOSFIRE on Keck 1**

Ian S. McLean[1]

[1]UCLA.

9:00 AM - 2:00 PM

On April 4, 2012 a new multi-object spectrometer and camera called MOSFIRE achieved “first light” at the Cassegrain focus of the 10-m Keck 1 telescope. MOSFIRE provides near infrared (0.97 to 2.45 microns) multi-object spectroscopy over a 6.14' x 6.14' field of view with a resolving power of R~3,500 for a 0.7" slit width (2.9 pixels in the dispersion direction). By changing from the grating to a mirror, MOSFIRE provides imaging over a field of view of 6.9' diameter with 0.18" per pixel sampling. A single diffraction grating can be set at two fixed angles, and order-sorting filters provide spectra that cover the K, H, J or Y bands by selecting 3rd, 4th, 5th or 6th order respectively. A folding flat following the field lens is equipped with piezo transducers to provide tip/tilt control for flexure compensation at the <0.1 pixel level. MOSFIRE is equipped with a cryogenic Configurable Slit Unit (CSU) developed in collaboration with the Swiss Center for Electronics and Microtechnology (CSEM). Under remote control the CSU can form masks containing up to 46 slits with ~0.01" precision. Reconfiguration time is <6 minutes and no thermal cycling of the instrument is required. Slits are formed by moving narrow bars from opposite sides of the focal plane. An individual slit has a length of 7.0" but bar positions can be aligned to make longer slits in increments of 7.5". MOSFIRE was built by a consortium involving Caltech, UCLA, UCSC and WMKO. Ian S. McLean (UCLA) and Charles C. Steidel (Caltech) are the principal investigators. MOSFIRE was funded by the NSF TSIP initiative and by a private donation to the Keck Observatory by Gordon and Betty Moore. Details are available at the Keck Observatory web site. MOSFIRE will be available for shared risk observing in 2012B.

522.03 – **ROBOSPECT: Automated Equivalent Width Measurement for Stellar Spectra**

Christopher Z. Waters[1], J. K. Hollek[2]

[1]Institute for Astronomy, [2]University of Texas.

9:00 AM - 2:00 PM

The study of stellar abundances requires the analysis of spectral features. The two methods of analysis are spectral synthesis and equivalent width measurement. Spectral synthesis requires models and other inputs, which makes reproducing the synthetic spectra of other studies difficult. The equivalent width of a line is simply a geometric characteristic and is therefore an easily repeatable measurement between different sets of spectra for a given star, without needing to account for differing treatments of the physics of abundance analysis between studies. Equivalent width measurement is typically achieved by fitting a Gaussian or Voigt profile to a spectral line using software that usually requires user input. As

different users may make different choices of the fitting parameters (such as the continuum placement), this introduces user-specific uncertainties into the fit quality. Automating this process allows the equivalent width measurement to be independent of these user-added uncertainties; however, there are few freely available programs that can accurately and precisely measure equivalent widths. We present a new program, ROBOSPECT, that does automate this measurement with minimal user interaction. This allows a consistent and repeatable set of measurements to be determined from the data without the added uncertainties due to user choices. ROBOSPECT is modular by design, allowing for different line models and continuum estimations to be selected based on the input spectrum. Comparing the results of ROBOSPECT to a sample of independently well measured spectral lines shows no systematic bias in the ROBOSPECT results, with a very tight scatter of 2.1 $AA{}$ for a S/N~100 stellar spectrum. We illustrate the suitability of ROBOSPECT to line measurement by presenting a sample of test fits over a range of spectrum type and signal to noise.

522.04 – **Serviceable Large Low Cost/Mass Infrared 4 Kelvin Telescope Passively Cooled**

Domenick Tenerelli[1], J. Tolomeo[1], A. Klavins[1], D. Putnam[1]

[1]*Lockheed Martin Space Systems Company.*
9:00 AM - 2:00 PM

An innovative space telescope concept was studied for the New Millenium program for ST6. The telescope called a Dual Anamorphic Reflector Telescope (DART) features two single curvature monolith parabolic surfaces. The telescope system personifies simplicity which extrapolates to low cost and mass. We at Lockheed Martin have implemented this design in two large prototypes that demonstrate imaging in the IR without the use of corrective optics as well as demonstrate the mass scaling advantageous of this architecture. A serviceable deployment concept is described which will enable apertures greater than 10m with areal density less than 10 kg/m2 to be realized for space applications. Because of the overall simplicity of the architecture the instrument section is easily replaceable when new detector technology is developed. In addition the simplicity of the overall architecture allows the system to assembled on the International Space Station (ISS). Anti sun pointing, low conductance support structure and deployable sun shade made of multiple deployable shields in an open groove configuration maintains telescope temperatures near 4K with minimal gradients

522.05 – **Next-generation Technologies for EUV Solar Imagers**

Dennis S. Martinez-Galarce[1], P. Boerner[1], R. Stern[1], R. Soufli[2], M. Fernández-Perea[2], L. Shing[1], J. Lemen[1], E. Gullikson[3]

[1]*Lockheed Martin Advanced Technology Center,* [2]*Lawrence Livermore National Laboratory,* [3]*Lawrence Berkeley National Laboratory.*
9:00 AM - 2:00 PM

The Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory has convincingly demonstrated the importance of obtaining high spatial (~ 1 arc sec) and temporal (~ 10 sec) resolution images of solar extreme ultraviolet (EUV) radiation from the transition region and corona. AIA full-disk observations indicate that such radiation is being generated by events or features at spatial scales ranging from large-sized events of ~ several arc min (e.g., CMEs and related flares), to much smaller scales observed at the limits of the performance of AIA (e.g., moss and jet-like features). Although our understanding of the solar atmosphere has advanced as a consequence of these observations, furthering our knowledge of the detailed physics will require improved instrumentation, i.e., fabrication of higher performance EUV imaging telescopes with higher spatial resolution ($\Delta\theta \leq 0.1$ arc sec) and higher temporal resolution ($\Delta t \leq$ few sec), extending over previously un-observed wavelength ranges. Such improved technologies, which are currently under development, can be implemented in the next-generation EUV solar telescopes (for example, on the *Solar-C* or *RAM* missions). Herein, we report on the status of three technologies that have been investigated: development of super-polished SiC substrates useful for large-diameter EUV telescopes; development of a novel multilayer coating that produces high reflectivities above 300 Å; and evaluation of new back-illuminated CMOS detector arrays capable of rapid EUV imaging.

522.07 – **SunPy: Python for Solar Physics Data Analysis**

V. Keith Hughitt[1], S. Christe[2], J. Ireland[1], A. Shih[2], F. Mayer[3], M. D. Earnshaw[4], C. Young[1], D. Perez-Suarez[5], R. Schwartz[6]

[1]*NASA/ADNET SYSTEMS,* [2]*NASA GSFC,* [3]*Technische Universitat Wien, Austria,* [4]*Blackett Laboratory, Imperial College, United Kingdom,* [5]*Trinity College Dublin, Ireland,* [6]*NASA/The Catholic University of America.*
9:00 AM - 2:00 PM

In recent years, Python, a free cross platform general purpose high-level programming language, has seen widespread adoption among the scientific community resulting in the availability of wide range of software, from numerical computation and machine learning to spectral analysis and visualization. SunPy is a software suite specializing in providing the tools necessary to analyze solar and heliospheric datasets in Python. It provides a free and open-source alternative to the IDL-based SolarSoft (SSW) solar data analysis environment. We present the current capabilities of SunPy which include WCS-aware map objects that allow simple overplotting of data from multiple image FITS files; time-series objects that allow overplotting of multiple lightcurves, and integration with online services such as The Virtual Solar Observatory (VSO) and The Heliophysics Event Knowledgebase (HEK). SunPy also provides functionality that is not currently available in SSW such as advanced time series manipulation routines and support for working with solar data stored using JPEG 2000. We present examples of solar data analysis in SunPy, and show how Python-based solar data-analysis can leverage the many existing data analysis tools currently available in Python. We discuss the future goals of the project and encourage interested users to become involved in the planning and development of SunPy.

522.08 – **How the Image Processing Pipeline Handles the Flood of Data from Pan-STARRS 1**

Heather Flewelling[1]

[1]*University of Hawaii.*
9:00 AM - 2:00 PM

Pan-STARRS 1 (PS-1) is a 1.8 meter telescope with a 1.4 Gigapixel camera, located in Haleakala, Hawaii. PS1's science mission began in May 2010, and roughly 500 exposures are taken each night. There are several surveys, with different requirements for image processing. The Image Processing Pipeline (IPP) is the group responsible for processing the PS1 data. The requirements to process this data is staggering. We have 138 machines, 2.3 TB of storage, and 4.4T of ram. The data is processed each night as it is taken, and is distributed to the consortium. This poster will show the different stages of processing, with various metrics showing the quality of data, time and resources needed. The PS1 Science Consortium consists of The Institute for Astronomy at the University of Hawai'i in Manoa, the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching, The Johns Hopkins University, the University of Durham, the University of Edinburgh, the Queen's University Belfast, the Harvard-Smithsonian Center for Astrophysics, the Los Cumbres Observatory Global Telescope Network Incorporated, the National Central University of Taiwan, and NASA.

522.09 – **Formation of interstellar anions**

Maria Luisa Senent[1]

[1]*IEM-CSIC, Spain.*
9:00 AM - 2:00 PM

Formation of interstellar anions: M.L. Senent. The recent detection of negative charged species in the ISM[1] has instigated enthusiasm for anions in the astrophysical community[2]. Many of these species are new and entail characterization. How they are formed in astrophysical sources is a question of major relevance. The anion presence in ISM was first predicted theoretically on the basis of electron affinities and on the negative linear chain molecular stabilities. Although very early, they were considered in astrochemical models[3-4], their discovery is so recent because their abundances seem to be relatively low. These have to be understood in terms of molecular stabilities, reaction probabilities and radiative and collisional excitations. Then, we present our theoretical work on even carbon chains type C_n and C_nH (n=2,4,6) focused to the understanding of anion abundances. We use highly correlated ab initio methods. We performed spectroscopic studies of various isomers that can play important roles as intermediates[5-8]. In previous papers[9-10], we compared C_2H and C_2H^- collisional rates responsible for observed line intensities. Actually, we study hydrogen attachment ($C_n + H \rightarrow C_nH$ and $C_n^- + H \rightarrow C_nH^-$) and associative detachment processes ($C_n^- + H \rightarrow C_nH + e^-$) for 2, 4 and 6 carbon atom chains[11]. [1] M.C.McCarthy, C.A.Gottlieb, H.Gupta, P.Thaddeus, *Astrophys.J,* 652, L141 (2006) [2] V.M.Bierbaum, J.Cernicharo, R.Bachiller, eds., 2011, pp 383-389. [3] A. Dalgarno, R.A. Mc Cray, *Astrophys.J,*, 181, 95 (1973) [4] E. Herbst E., Nature, 289, 656 (1981); [5] H.Massó, M.L.Senent, P.Rosmus, M.Hochlaf, J.Chem.Phys., 124, 234304 (2006) [6] M.L.Senent, M.Hochlaf, *Astrophys. J.* , 708, 1452(2010) [7] H.Massó, M.L.Senent, J.*Phys.Chem.A*, 113, 12404 (2009) [8] D. Hammoutene, M.Hochlaf, M.L.Senent, submitted. [9] A. Spielfiedel, N. Feautrier, F. Najar, D. ben Abdallah, F. Dayou, M.L. Senent, F. Lique, Mon.Not.R.Astron.Soc., 421, 1891 (2012) [10] F.Dumouchel, A, Spielfieldel , M.L.Senent, N.Feautrier, Chem. Phys. Lett., 533, 6 (2012) [11] M.L.Senent, M.Hochlaf, submitted

523 – Stars, Star Formation, Supernovae, Etc.

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

523.01 – **The Relation Between Hydrogen Column Density and Optical Extinction for Supernova Remnants from the Chandra Archive**

Dillon Foight[1], P. Slane[1], T. Guver[2], F. Ozel[2]

[1]*Smithsonian Astrophysical Observatory,* [2]*University of Arizona.*
9:00 AM - 2:00 PM

The linear relationship between optical extinction (A_V) and hydrogen column density (N_H) has long been observed and utilized to link distance estimates for X-ray sources with absorption values. A recent approach to accurately defining this relationship has been to collect published values of N_H from spectral fits to X-ray observations of supernovae remnants (SNR), and of A_V from line ratios, nearby stars, or extinction maps. While this approach has the advantage of a potentially large number of points to constrain the slope, it has the downside of being susceptible to any unreported systematic errors, which may be different for each selected SNR. Given that the vast majority of these SNR have been observed with the Chandra Space Telescope, and have publicly available data, we have independently determined the N_H for ~20 SNR in a self-consistent manner. We find that discrepancies between our N_H values and previously published values can

readily be attributed to the choice of abundances used in the spectral fitting. With these new N_H values, along with new A_v values from Balmer decrement observations, we can recalculate the slope of the linear relation. As this relation is commonly used to help constrain the distance to X-ray sources, subtle changes in this relation can have important consequences for a variety of astrophysical applications.

523.02 – **Finding Short-Term Variability in Methanol Masers**

Samuel Bonin[1], W. C. Barott[2], T. Catanach[3]

[1]*University of New Mexico,* [2]*Embry-Riddle Aeronautical University,* [3]*University of Notre Dame.*

9:00 AM - 2:00 PM

The Allen Telescope Array (ATA) performed 53 observations of 6.7 GHz methanol masers between July 2010 and January 2011 in an effort to identify short-timescale variability. With the notable exception of Weisberg *et al.* (2005), few analyses have been performed analyzing variability in masers on timescales of minutes or less. This work is aimed both at providing additional data (including refined positions) on the catalog of observed sources as well as identifying the prevalence and cause of short-term phenomena. Observations utilized both the ATA correlator (for mapping) and beamformer (for recording voltage time series). A combination of Fast-Fourier Transforms and Continuous Wavelet Transforms are applied to channelized power series waterfalls) in this investigation. Wavelet analysis can be thought of as a generalization of Fourier analysis that allows us to examine non-stationary characteristics of the spectra. The survey included both short (10 minute), long (60 minute), and follow-up observations on candidate targets. Analysis so far has identified three variable sources out of 43 distinct objects that were observed. These objects exhibit significant variation on the order of several minutes, are consistent in follow-up observations, and we have ruled out instrumental variation. Future and ongoing work includes identifying the source of this variation as intrinsic to the source or a property of the ISM. Shorter time-scales will be investigated using a combination of techniques, including total power variation, pulse searching (in an attempt to find pulsars), and phase-shift demodulation techniques. The case for SETI analysis of these data is given, for example, by Cordes (1993), who suggested that extraterrestrial intelligences could use masers to amplify interstellar signals.This project was funded by the National Science Foundation Grant AST0852095. [1] Weisberg J. M. et al. (2005) Science, 309, 5731. [2] Cordes J. M. (1993) Astron. Soc. Pacific Conf. Series, 47, 257.

523.03 – **Abundances in Red Giant Stars in IC 4756**

Julie Djordjevic[1], J. King[1]

[1]*Clemson University.*

9:00 AM - 2:00 PM

We present high-resolution spectroscopy of red giant stars in the open cluster IC 4756 from the McDonald Observatory 2.1m. Results include relative abundance measurements as well as stellar atmospheric parameters. This work is supported by NSF grant AST 09-08342 to JRK. The observations were originally supported by NASA through the grant HF-1046.01-93A to JRK from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc. under NASA Contract No.NAS 5-26555.

523.04 – **XMM-Newton And Chandra Observations Of The Galactic Mixed-morphology Supernova Remnant G352.7-0.1**

Thomas Pannuti[1], J. P. Napier[1]

[1]*Morehead State University.*

9:00 AM - 2:00 PM

We present an analysis of pointed archival X-ray observations made with XMM-Newton and Chandra of the Galactic mixed-morphology supernova remnant (SNR) G352.7-0.1. Mixed-morphology SNRs feature a shell-like radio morphology with a contrasting center-filled thermal morphology: the origin of the contrasting morphologies observed for these sources is not well-understood, thus necessitating further study of these remarkable objects. Previous X-ray observations made of this SNR have revealed the presence of an ejecta-dominated plasma with enhanced elemental abundances of silicon and sulfur) along with a remarkably high temperature of approximately kT ~ 2 keV. We present a spatially-resolved spectroscopic study of this emission to search for spectral and spatial variations in the X-ray-emitting plasma: we also conduct a search for a neutron star. Initial results will be presented and discussed.

523.05 – **Optical Monitoring and Period Analysis of High Mass X-Ray Binary System BD+53 2262**

Nathaly Zurita[1], E. G. Hintz[1]

[1]*Brigham Young University.*

9:00 AM - 2:00 PM

High mass X-ray binary systems (HMXB) are usually composed of a B spectral type star and a neutron star. These systems have been primarily observed in the X-ray regime and as such their optical properties have not been thoroughly studied. We hypothesize that variability/periodicity in the optical brightness should be present and correlate with variability at other wavelengths. For the last five summers, optical observations of HMXB system BD+53 2262 have been gathered on the David Derrick 16'' telescope located at Brigham Young University. To probe for long-term and short term variability, observations were taken in quick succession in one filter over the course of a night and also shorter observations through multiple filters spaced over many nights. The observations are primarily in the Johnson V filter, with B and I added in 2010, and R in 2011. We present optical light curves for five years of observations of the system BD+53 2262. There is a definite decrease in magnitude in the past five years and small monthly variations in three of the four years. These indicate a long term periodicity on the range of years and some shorter term periodicity in the range of months, consistent with what was expected. Period analysis has been done on the data and preliminary results will be presented. We will keep observing this system to see if there is further evidence of long term periodicity and to see if the monthly variations continue.

523.06 – **The HETG Orion Legacy Project: Abundances in Trapezium Stars**

Norbert S. Schulz[1], D. P. Huenemoerder[1], N. Shen[1], P. Testa[2], J. Nichols[2], C. R. Canizares[1]

[1]*MIT,* [2]*CfA.*

9:00 AM - 2:00 PM

The ONC is an ideal astrophysical laboratory to study very young stars. The HETG Orion Legacy Project is designed to obtain a large number of high-resolution X-ray spectra of very young late type pre-main sequence stars, and several young massive and intermediate mass stars. Its extreme proximity and youth makes the core of the ONC a Chandra legacy project involving the only high resolution spectroscopic study of young embedded cluster stars for decades to come. For several PMS stars we derive abundance fractions from temperature-insensitive line ratios. From these fractions we construct a single abundance distribution involving O, Mg, Ne, Si, S, Ar, and Fe to fit all X-ray spectra simultaneously. We compare this common abundance distribution to abundances determined recently in more massive Orion Trapezium stars and to results from several other abundance studies of Orion stars and clusters.

523.07 – **Weak Emission Lines in the NIR Spectrum of 3 Cen A**

Glenn Michael Wahlgren[1], M. F. Nieva[2], N. Przybilla[2]

[1]*NASA-HQ/CUA,* [2]*Univ. Erlangen-Nuremberg, Germany.*

9:00 AM - 2:00 PM

Infrared spectral observations of the chemically peculiar star 3 Cen A (B5p) have been made as part of the CRIRES-POP program to observe bright stars at high spectral resolution using the ESO/VLT/CRIRES instrument. The program has been described by Lebzelter et al (2012, A&A, 539, 109). Here, we discuss the detection of weak emission lines (WELs) arising from singly-ionized elements, including P, Mn, and Fe. The emission lines at IR wavelengths complement the emission lines catalogued for this star at optical wavelengths (Wahlgren & Hubrig, 2004, A&A, 418, 1073). We aim to extend the system of energy levels associated with WELs to higher energy to identify the mechanism of their creation. We have performed NLTE modeling at optical and NIR wavelengths for several species. Early results from modeling of Fe II shows that NLTE effects can be large and in a manner that improves the synthetic spectrum fit of the observations compared with LTE synthetic spectrum modeling.

523.08 – **Complex Scattered Radiation Fields And Multiple Magnetic Fields In The Protostellar Cluster In NGC 2264**

Jungmi KWON[1], M. Tamura[1], R. Kandori[2], N. Kusakabe[2], J. Hashimoto[2], Y. Nakajima[2], F. Nakamura[2], T. Nagayama[3], T. Nagata[4], J. H. Hough[5], M. W. Werner[6], P. S. Teixeira[7]

[1]*NAOJ/GUAS, Japan,* [2]*NAOJ, Japan,* [3]*Nagoya University, Japan,* [4]*Kyoto University, Japan,* [5]*University of Hertfordshire, United Kingdom,* [6]*Jet Propulsion Laboratory, California Institute of Technology,* [7]*European Southern Observatory, Germany.*

9:00 AM - 2:00 PM

Near-infrared imaging polarimetry in the J, H, and Ks bands has been carried out for the protostellar cluster region around NGC 2264 IRS 2 in the Monoceros OB1 molecular cloud. Various infrared reflection nebula clusters (IRNCs) associated with NGC 2264 IRS 2 and the IRAS 12 S1 core, as well as local infrared reflection nebulae (IRNe), were detected. The illuminating sources of the IRNe were identified with known or new near- and mid-infrared sources. In addition, 314 point-like sources were detected in all three bands and their aperture polarimetry was studied. Using a color-color diagram, reddened field stars and diskless pre-main-sequence stars were selected to trace the magnetic field structure of the molecular cloud. The mean polarization position angle of the point-like sources is ~80 degrees in the cluster core, and ~60 degrees in the perimeter of the cluster core, which is interpreted as the projected direction on the sky of the magnetic field in the observed region of the cloud. The Chandrasekhar-Fermi method gives a rough estimate of the magnetic field strength to be about 100 micro-Gauss. A comparison with recent numerical simulations of the cluster formation implies that the cloud dynamics is controlled by the relatively strong magnetic field. The local magnetic field direction is well associated with that of CO outflow for IRAS 12 S1 and consistent with that inferred from submillimeter polarimetry. In contrast, the local magnetic field direction runs roughly perpendicular to the Galactic magnetic field direction.

523.09 – **The Photometric Period and Variability of the Cataclysmic Variable V849 Herculis (PG 1633+115)**

Fred Ringwald[1], G. D. Rude, II[1], J. J. Roveto[1], K. K. Khamvongsa[1]

[1]*California State University, Fresno.*

9:00 AM - 2:00 PM

We report time-resolved photometry of the cataclysmic variable V849 Her, and measure a period of 0.1414 ± 0.0030 days (3.394 ± 0.072 h). We also present photometry taken over several weeks in 2010 and 2011, as well as light curves from 1995 to 2011 by the American Association of Variable Star Observers. The spectra, absolute magnitude derived from infrared magnitudes, and variability all suggest that V849 Her is a nova-like variable. The shallow (0.5-magnitude) low states we observe resemble the erratic low states of the VY Sculptoris stars,

although they may recur quasi-periodically over an average cycle of 12.462 ± 0.074 days.

523.1 – **Warm H2O And OH Disk Emission In 1548c27**

Greg Doppmann[1], J. Najita[2], J. Carr[3]

[1]W. M. Keck Observatory, [2]NOAO, [3]NRL.

9:00 AM - 2:00 PM

Circumstellar disks are fundamentally important in the formation of stars and planets, and high resolution L-band spectra provide an essential tool for characterizing the inner disk region (< 1AU) around young stars where terrestrial-like planets may form. By extending our modeling technique developed for fitting the disk emission features in V1331 Cyg, we model the broad water and OH emission that is observed in the probable Herbig AeBe star, 1548C27, from our NIRSPEC/Keck L-band spectra (R=24,000). We use the HITEMP line list to model the water emission in 1548C27, which gives an improved fit to V1331 Cyg compared with models using the BT2 list. When compared to V1331 Cyg, the water and OH model fits to 1548C27 reveal (1) similarly high temperatures (T ~ 1500K), indicating that the emission originates from the inner disk, (2) similarly high columns of OH and water (N ~ 10^{21}–10^{22} cm^{-2}), suggesting a deeper temperature inversion in the disk atmosphere, and (3) rapid disk rotation (vsini > 60 km s^{-1}), indicating a more edge-on disk orientation along our line-of-sight.

523.11 – **Hidden Gems: Resolving M/L Dwarf + T Dwarf Binaries**

Christopher R. Gelino[1], A. J. Burgasser[2]

[1]Caltech, [2]UCSD.

9:00 AM - 2:00 PM

The multiplicity properties of very low mass stars and brown dwarfs are critical empirical constraints for formation theories, while multiples themselves provide unique opportunities to test evolutionary and atmospheric models and examine empirical trends. Existing samples of late-type binaries are drawn almost entirely from resolved imaging programs, limiting our understanding of the closely-separated binary population for which dynamical mass measurements and transit observations are most likely. We have developed a method for identifying and characterizing unresolved, late-type M/L dwarf + T dwarf binaries using low-resolution, near-infrared spectroscopy, a method that is not constrained by separation limitations. We have obtained high resolution imaging with Keck NIRC2 LGS-AO for approximately 30 candidate binaries identified by this method. In this poster we characterize the most widely-separated, resolved systems and set limits on the separations of unresolved systems. The former provide necessary information for characterizing the still poorly-understood L dwarf/T dwarf transition and the first epochs for astrometric orbit determinations; the latter are optimal targets for high resolution, spectroscopic monitoring.

523.12 – **Photometric and Spectroscopic Analysis of Eclipsing Binary TY Tau**

Jennifer Wojno[1], C. H. S. Lacy[2]

[1]University of Louisville, [2]University of Arkansas.

9:00 AM - 2:00 PM

We have used photometric observations collected from November 2000 to December 2010 using the 10" URSA telescope at the University of Arkansas as well as spectroscopic observations from other sources of the eclipsing binary system TY Tau to determine the relative radii, mass, and luminosities of the stars in the system. These results suggest that this system consists of on ZAMS or near-ZAMS early K star and a companion which has not yet reached the ZAMS. The solution also suggests that there may be a third member of this system, although we cannot exclude contamination by an external source from these observations. Further observations of this system may refine the ages of these stars, and also determine whether there is a distant third member of this system or whether the residual flux is due to an unrelated object.

523.13 – **Two Different Sources of Water in Earth’s Accretion Zone of the Solar Nebula**

Ekkehard Kuehrt[1], C. Tornow[1], S. Kupper[1], P. Gast[1]

[1]DLR-German Aerospace Center, Germany.

9:00 AM - 2:00 PM

The origin of water and the related significance for the early Earth depend on the conditions in the different stages of the solar nebula and the later solar system. With our model we simulate the chemical and hydrodynamic processes of the solar nebula. For that purpose we explicitly consider the evolution of the parental cloud core, its gravitational collapse, and the resulting turbulent disk. As a consequence of the low temperature (~8 K) in the center of the cloud core thick ice layers are formed on the dust grains. The collapse is simulated using a new semi-analytic multi-zone solution of the hydrodynamic equations which is valid for spherical symmetry. Initially, the density distribution of the inner zone represents a central clump from which the proto-sun and later the T Tauri Sun form. The two outer zones evolve into a disk and a thin but spatially extended envelope. The disk stage is described by a stationary model and considers a weakly coupled gas and dust phase. We have identified two different sources of water for the region of Earth’s accretion. The first source is located in the inner region of the collapsing cloud core where the temperature could reach about 500 K. There, water was produced efficiently by gas phase reactions between neutral molecules. The second source is related to icy mantles of dust grains formed in the cloud core and disk stage. In the course of disk evolution cooling caused an enrichment of the dust phase with water ice beyond the snowline which moved inwards, i.e. into the Earth accretion zone. In addition we present results how water formation is related to the initial abundance ratio between carbon and oxygen in the cloud. This research has been supported by the Helmholtz Association through the research alliance “Planetary Evolution and Life“.

523.14 – **Probing the Circumstellar Environment of the Herbig Ae Star MWC 325**

Sam Ragland[1], K. Ohnaka[2], L. Hillenbrand[3], S. T. Ridgway[4], M. M. Colavita[5], R. Akeson[6], W. Cotton[7], W. C. Danchi[8], M. Hrynevych[1], R. Millan-Gabet[6], W. A. Traub[5]

[1]W. M. Keck Observatory, [2]Max-Planck-Institut für Radioastronomie, Germany, [3]California Institute of Technology, [4]National Optical Astronomy Observatories, [5]Jet Propulsion Laboratory, California Institute of Technology, [6]NExScI, California Institute of Technology, [7]National Radio Astronomy Observatory, [8]NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics.

9:00 AM - 2:00 PM

We present the first N-band nulling plus K- and L-band squared-visibility observations of a young stellar object, MWC 325, taken with the 85 m baseline Keck Interferometer. Interferometric observations of MWC 325 at K, L and N encompass a factor of five in spectral range and thus, especially when spectrally dispersed within each band, enable characterization of the structure of the inner disk regions where planets form. Fitting our observations with geometric models such as a uniform disk or a Gaussian disk show that the apparent size increases monotonically with wavelength in the 2-12 micron wavelength region, confirming the widely held assumption based on radiative transfer models, now with spatially resolved measurements over broad wavelength range, that disks are extended with a temperature gradient. The existing interferometric measurements and the spectral energy distribution can be reproduced by a flat disk or a weakly-shadowed nearly flat-disk model, with only slight flaring in the outer regions of the disk, consisting of representative "sub-micron" and "micron" grains of a 50:50 ratio of silicate and graphite. This is marked contrast with the disks previously found in other Herbig Ae/Be stars suggesting a wide variety in the disk properties among Herbig Ae/Be stars.

523.15 – **The Core Velocity Dispersion (CVD) for Taurus Dense Core Clusters**

Di Li[1], L. Qian[2]

[1]California Institute of Technology, [2]National Astronomical Observatories, China.

9:00 AM - 2:00 PM

We define a statistical measurement--Core Velocity Dispersion (CVD) for the dynamics of a dense core cluster. To obtain a well defined CVD requires a spectroscopic dense core sample located in a contiguous region. We measure CVD for Taurus cores utilizing the ~100 d^2 13CO map corrected for depletion. The Taurus CVD has the same power law as that of the Larson's law. No sign of additional energy input is seen.

523.16 – **Understanding Star Formation in the Rosette Molecular Complex: A Chandra View of the Embedded Young Clusters**

Junfeng Wang[1]

[1]Harvard-Smithsonian CfA/SAO.

9:00 AM - 2:00 PM

The Rosette Molecular Cloud (RMC) complex represents an ideal laboratory for understanding star formation processes, and we have carried out a Chandra imaging survey of the embedded clusters to characterize the young stellar populations. We present new X-ray results on the embedded young star cluster RMC PL6 and in particular the massive young stellar object AFGL 961, which is previously resolved in the near-infrared (the Rosette Eye, Li et al. 2008).

523.17 – **Spectropolarimetry and Type Ia Supernovae**

Amber L. Porter[1], M. Leising[1]

[1]Clemson University.

9:00 AM - 2:00 PM

Spectropolarimetry of Type Ia supernovae sheds lights on the asymmetric outermost geometry of these cataclysmic events. Non-zero polarization detections hint at a roughly spherical photosphere enveloped in ejected material with the supernova becoming more spherical with time as we see deeper into the ejecta. Further study is needed to determine the nature of the asymmetry, among possibilities such as clumping or non-spherical ejection. We investigate how a supernova’s ejecta velocity distribution is correlated to the polarization of certain spectral features for different origins of asymmetry.

523.18 – **The Properties and Kinematics of a New Sample of Cool Subdwarfs from SDSS**

Antonia Savcheva[1], A. A. West[1], J. Bochanski[2]

[1]Boston Univ., [2]Pennsylvania State University.

9:00 AM - 2:00 PM

We present a sample of 2114 M subdwarfs from the 7th Data Release of the Sloan Digital Sky Survey (DR7; SDSS). This catalog contains stellar coordinates, SDSS magnitudes, spectral classes, radial velocities, proper motions, absolute magnitudes and estimated distances. We discuss the selection criteria, the spectral classification and radial velocity determination processes. We calculate 3D space motions (U,V,W) in the standard Galactic system and place each star in its proper subdwarf subclass (as defined by Lepine et al.). We show that the metal poor populations are moving faster than the metal rich stars on average, consistent with being members of a dynamically heated thick disk or halo population. In addition, we present two different versions of the reduced proper motion (RPM) diagram, including a new formulation of the classic RPM diagram that includes information about the radial velocity. We discuss a few curious subsets of our sample, including

active stars, late ultra subdwarfs, and candidate high velocity star.

523.19 – **Eclipsing Binaries through the Double Looking Glass of Kepler and Keck**

Lauren M. Weiss[1], G. Marcy[1], J. Orosz[2], W. Welsh[2], A. Prša[3], J. Richards[1], S. Gegenheimer[1], J. S. Bloom[1]

[1]*UC Berkeley,* [2]*San Diego State University,* [3]*Villanova U.*.

9:00 AM - 2:00 PM

The Kepler Space Telescope has detected a panoply of physical effects in binary star systems to unprecedented precision, in particular the relativistic Doppler beaming signature. We present Keck/HIRES radial velocity measurements of four Kepler Input Catalog (KIC) eclipsing binaries. We compute self-consistent solutions to the eclipsing binaries by fitting the light curve and radial velocities simultaneously with the legacy code ELC. We also attempt a novel two-dimensional radial velocity fitting technique to solve for the velocity of the primary and secondary star in each system. Our velocity fitting procedure draws from a library of over 700 Keck/HIRES spectra of stars with known effective temperature, surface gravity, and metallicity to construct a composite spectral template from which we can measure the velocities of both stars. We discuss the orbital dynamics and stellar physics of these four KIC systems, including ellipsoidal variations, relativistic Doppler beaming, spot activity, pulsations, and third-body, low-mass companions of the binary systems. In particular, we note that long-lived spot activity in tidally synchronous binary systems can produce long-lived asymmetries in the light curve before and after the primary eclipse. These asymmetries can masquerade as the relativistic Doppler beaming signature, and we caution beaming enthusiasts to consider spot activity before attributing light curve asymmetries to relativistic beaming.

523.2 – **New Ultraluminous Supersoft Source in the Small Magellanic Cloud: MAXI J0158-744**

Kwan Lok Li[1], T. Lu[1], A. Kong[1]

[1]*National Tsing Hua University, Taiwan.*

9:00 AM - 2:00 PM

We present a time-resolved analysis of an ultraluminous supersoft source (SSS) MAXI J0158-744 using 18 consecutive follow-up Swift ToO observations. MAXI J0158-744 is an ultraluminous soft X-ray outburst with a peak luminosity up to 4.3 10^39 erg/s in the energy range of 0.2-2.0 keV located in the Magellanic Bridge region, detected by MAXI/GSC on 11 November 2011. Follow-up Swift observations confirmed that the X-ray emissions are ultra-soft, which could be well fitted by blackbody models of temperatures down to 52 eV. Since the onset, the X-ray emission decreased exponentially dropping from $10^39 to 10^37 erg/s in 15 days (assuming the Small Magellanic Cloud distance) and fell below the detection limit of Swift after 09 December 2011. The earliest Swift X-ray spectra show K-edge absorption (0.88 keV) and a broad Lya (0.65 keV) from OVIII, which indicate that it could be an oxygen rich system. Swift UVOT also caught the outburst in U band with magnitude 13.07 on 12 November 2011 and it returned to quiescence with magnitude 13.6 two days later. During this quiescence, we performed two ATCA radio observations at frequencies 5.5 GHz and 9 GHz with the baseline ranging from 337 m to 6 km and constrained an upper limit of 45 micro-Jansky at the X-ray position. By comparing the object with the close-binary soft source (CBSS) model, we therefore concluded that MAXI J0158-744 could be a slowly accreting O-rich white dwarf binary, with unstable hydrogen burning on the WD surface. Remarkably, ultraluminous SSSs are very rare high-energy phenomena and this nearest one MAXI J0158-744 provided a very unique opportunity for us to understand the underlying physics of such a system.

523.21 – **Chandra and HST Studies of the X-ray Sources in Galactic Globular Clusters**

Ting-Ni Lu[1], A. Kong[1], S. F. Anderson[2], C. Bassa[3], W. H. G. Lewin[4], D. Pooley[5], F. Verbunt[3]

[1]*National Tsing Hua University, Taiwan,* [2]*Department of Astronomy, University of Washington,* [3]*SRON, Netherlands Institute for Space Research, Netherlands,* [4]*Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology,* [5]*Eureka Scientific, Inc.*.

9:00 AM - 2:00 PM

The binary content in globular clusters is crucial for the dynamical evolution of globular clusters. Studying the X-ray sources population would be an efficient method to explore the binary content since most of the X-ray sources in globular clusters are close binaries. The X-ray sources population comprises various exotic binaries: low mass X-ray binaries, cataclysmic variables, millisecond pulsars, or chromospherically active binaries. By using Chandra and HST data, we would be able to observe and identify the X-ray sources in globular clusters. In order to study the possible formation origins of the X-ray sources in globular clusters, we construct the correlation for the X-ray source number and the physical parameters (core radius, core density, and metallicity) from ~20 globular clusters. With the correlation, we would be able to predict the X-ray source number in globular clusters and to constrain their formation mechanisms -- if they are formed through dynamical interactions or from primordial binaries.

523.22 – **Evla Observations Of Thioxoethenylidene In The Taurus Molecular Cloud Complex**

Nirupam Roy[1], A. Datta[2], E. Momjian[1], A. P. Sarma[3]

[1]*National Radio Astronomy Observatory,* [2]*Center for Astrophysics & Space Astronomy,* [3]*DePaul University.*

9:00 AM - 2:00 PM

We report results from the EVLA observations of three dense molecular cores TMC-1, TMC-1C and L1521B in the Taurus Molecular Cloud complex to image the thioxoethenylidene (CCS) emission. This molecule is a tracer of dense molecular clouds, and a good candidate for Zeeman splitting observations. We found the CCS emission detected in our observation to be clumpy, tracing the starless cores. However, the clumpy emission is less than 15% of the total integrated emission detected in earlier single-dish observations. Clearly, significant large scale diffuse emission is present in these molecular clouds with favorable conditions for producing CCS. We are carrying out further high spatial and spectral resolution observations of other molecules present in the same region to understand the detailed physical condition of these dense molecular cores.

523.23 – **Mass Measurements of Black Holes in X-Ray Transients: Is There a Mass Gap?**

Laura Kreidberg[1], C. D. Bailyn[2], W. M. Farr[3], V. Kalogera[3]

[1]*University of Chicago,* [2]*Yale University,* [3]*Northwestern University.*

9:00 AM - 2:00 PM

We present a framework to estimate the systematic error in mass measurements of stellar mass black holes. We find that the dominant error arises from assuming zero or constant emission from the accretion disk when fitting orbital inclination. To quantify the effects of these assumptions, we develop a method to characterize the time variability of disk emission in X-ray binary lightcurves based on long-term monitoring of the source A0620-00. Using this characterization, we simulate a large sample of A0620-00 lightcurves and fit each of them for inclination with a star-only model of ellipsoidal variability. The resulting inclination estimates are typically 10° less than the value obtained by Cantrell et al. (2010), which accounts for variable disk emission. The systematic error due to neglecting disk emission can be predicted from the nonstellar light (NSL) fraction of the lightcurve. We use this result to generalize the systematic error for A0620-00 to 15 additional sources. We estimate the NSL fraction of each system by scaling the typical NSL fraction of A0620-00 relative to the system's orbital parameters. The mass estimates that incorporate these calculated errors are as much as 2.3 times smaller than other estimates in the literature. Using the corrected mass estimates, we perform a Bayesian analysis of the mass distribution. The distribution inferred from fitting a power law model peaks near 8 solar masses and falls off sharply above 10 solar masses. In contrast to prior studies of the mass distribution, our analysis does not produce a significant gap between the smallest black hole mass and the maximum theoretical neutron star mass.

523.24 – **The Supernova Spectropolarimetry Project; A Study of the Evolution of Aspherical Stellar Explosions**

George Grant Williams[1], P. Smith[2], N. Smith[2], P. Milne[2], J. Hoffman[3], L. Huk[3], D. Leonard[4], L. Dessart[5]

[1]*MMT Observatory,* [2]*Steward Observatory,* [3]*University of Denver,* [4]*SDSU,* [5]*OAMP, France.*

9:00 AM - 2:00 PM

We will present initial results from a project we have undertaken that is aimed at completing a long term comprehensive spectropolarimetric survey of all types of core collapse and thermonuclear supernovae. The principal goal of this effort is to improve our understanding of the characteristics and importance of asymmetries in supernova explosions by focusing on the observable evolution. In recent years, evidence has grown that nearly all supernovae exhibit departures from spherical symmetry.These results, together with advances in computing power that enable full three dimensional modeling, are exposing the possibility that asymmetries are not just observable consequences of supernovae, but may in fact be a necessity of the explosion mechanism itself. Here we present initial results from observations of the brightest core collapse and thermonuclear explosions obtained on a temporally well sampled basis at the 61" Kuiper, the 90" Bok, and the 6.5-m MMT telescopes using the CCD Imaging/Spectropolarimeter (SPOL) instrument.

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524 – Galaxies, Galaxy Clusters and Related Topics

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

524.01 – **Star Formation History of Dwarf Galaxies at z>1 From HST Grism Spectroscopy**

Hakim Atek[1]

[1]*Caltech.*

9:00 AM - 2:00 PM

Using the grism spectroscopy of the Wide Field Camera 3 onboard HST, we present a sample of star-forming galaxies selected by their emission lines at z > 1, comprising the peak of star-formation history of the Universe. These dwarf galaxies experience an intense episode of star-formation and have lower masses than typical samples at the same redshift. We will discuss the properties of these high-redshift starburst galaxies and their contribution to the total star-formation density.

524.02 – **Spectroscopic Indicators Of The Ionizing Flux And Radius Of The BLR Of AGN**

Gregory A. Shields[1], A. C. Stevens[1], K. L. Smith[2]

[1]*Univ. of Texas,* [2]*Univ. of Maryland.*

9:00 AM - 2:00 PM

We examine emission-line diagnostics of the flux of ionizing photons incident on the broad line region of active galactic nuclei. Such indicators have the potential to give corrections to the standard radius-luminosity relation for AGN, giving improved estimates of the radius of the BLR and the mass of the central black hole.

524.03 – **Star Formation Intensity, Gas Pressures, And Feedback**

Sangeeta Malhotra[1], J. Monkiewicz[1]

[1]*Arizona State Univ.*.

9:00 AM - 2:00 PM

We use [CII] and [OI] fine-structure lines and PDR models to derive average gas pressures in warm neutral gas for nearby galaxies. We find a strong correlation between star-formation intensity (SFI i.e. star-formation rate per unit area) and gas pressure. The average dust temperature also correlates with SFI. The star-formation intensity is derived using FIR and UV measurements from IRAS and GALEX. We also examine the relationship of pressure to total UV and IR luminosity, and find that the correlation is much weaker, suggesting that star formation intensity is a more fundamental indicator of the global state of a galaxy's ISM than is the total amount of star formation. The gas pressures range between log(P)=4-7 K/cm^3. The upper end of the pressure range is comparable to pressures in H II regions in starburst galaxies, which also corresponds to the pressure and surface brightness at which starbursts saturate. We also discuss the implications of this result for detecting [CII] line in high redshift galaxies with ALMA and Herschel.

524.04 – **1.1 mm Observations of the MBM12 Molecular Cloud**

Sungeun Kim[1], M. Kim[1], S. Youn[1], M. S. Yun[2], G. W. Wilson[2], I. Aretxaga[3], J. P. Williams[4], D. H. Hughes[3], A. Humphrey[3], J. E. Austermann[5], T. A. Perera[6], P. D. Mauskopf[7], L. Magnani[8]

[1]*Sejong University, Korea, Republic of,* [2]*UMass,* [3]*INAOE, Mexico,* [4]*University of Hawaii,* [5]*University of Colorado,* [6]*Wesleyan University,* [7]*Cardiff University, United Kingdom,* [8]*The University of Georgia*.

9:00 AM - 2:00 PM

We present 1.1 mm observations of the dust continuum emission from the MBM12 high-latitude molecular cloud observed with the Astronomical Thermal Emission Camera (AzTEC) mounted on the James Clerk Maxwell Telescope (JCMT) on Mauna Kea, Hawaii. Eight secure individual sources were detected with over 4.4 signal-to-noise ratio. These eight AzTEC sources can be considered to be real astronomical objects compared to the other candidates based on calculations of the false detection rate (FDR). The distribution of the detected 1.1 mm sources or compact 1.1 mm peaks is spatially anti-correlated with that of the 100 microm emission and the CO emission. We detected the 1.1 mm dust continuum emitting sources associated with two classical T Tauri stars, LkHalpha 262 and LkHalpha 264. Observations of spectral energy distributions (SEDs) indicate that LkHalpha 262 is likely to be Class II (pre-main sequence star), but there are also indications that it could be a late Class I (protostar). A flared disk and a bipolar cavity in the models of Class I sources lead to more complicated SEDs. From the present AzTEC observations of the MBM12 region, it appears that other sources detected with AzTEC are likely to be extragalactic and located behind MBM12. Some of these have radio counterparts and their star-formation rates (SFRs) are derived from a fit of the SEDs to the photometric evolution of galaxies in which the effects of a dusty interstellar medium have been included. This research was supported in part by Mid-career Researcher Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology 2011-0028001.

524.05 – **Highlights From The Comprehensive Analysis Of 650 Gamma Ray Bursts (nov 2004 - Dic 2010)**

Guido Chincarini[1], R. Margutti[2], M. Bernardini[3], E. Zaninoni[4]

[1]*University Milano Bicocca & Brera Observatory, Italy,* [2]*Harvard University & CfA,* [3]*Osservatorio Astronomico Brera - INAF, Italy,* [4]*Padua University and Osservatorio Astronomico - Brera - INAF, Italy*.

9:00 AM - 2:00 PM

We summarize the main findings of a comprehensive statistical analysis (http://arxiv.org/abs/1203.1060, http://arxiv.org/abs/1203.1059) we carried out on 650 Gamma Ray Bursts discovered by Swift and other facilities between launch (24 November 2004) and December 2010. The large sample and the many redshifts collected by various authors allowed us to constrain the X ray properties from a statistical perspective. In particular we could estimate the emitted energy in the various phases of the decaying light curve with reference to the intrinsic time scale of the various episodes. We show that Short GRBs decay faster, are less luminous and less energetic than long GRB, but are characterized by very similar intrinsic absorption. Of particular relevance the discovery of the three - parameters correlation $E_{X,iso}$, E_{peak} and $E_{X,iso}$. This correlation is shared by long, short and low energetic GRBs. The analysis seems to indicate that the Lorentz factor of the outflow regulates the GRB properties of the GRBs.

524.06 – **Halo Occupation Properties of X-ray AGNs**

Svetlana Starikova[1], R. Cool[2], D. Eisenstein[3], W. Forman[3], C. Jones[3], R. Hickox[4], C. Kochanek[3], A. Kravtsov[5], S. Murray[6], A. Vikhlinin[3]

[1]*Smithsonian Astrophysical Observatory,* [2]*Department of Astrophysical Sciences, Princeton University,* [3]*Harvard-Smithsonian Center for Astrophysics,* [4]*Dartmouth College,* [5]*Department of Astronomy and Astrophysics, University of Chicago,* [6]*John Hopkins University*.

9:00 AM - 2:00 PM

We discuss clustering properties of AGNs detected by the Chandra X-ray Observatory in the Bootes field over a redshift interval from z=0.17 to z~3. The measured correlation lengths are consistent with no redshift trend within the sample. The availability of accurate spectroscopic redshifts allows us to use the two-point correlation functions projected on the sky plane and in the line of sight to show that the X-ray AGNs are predominantly located at the centers of dark matter halos with Mtot > 4.1*10^{12}h^{-1}Msun, and tend to avoid satellite galaxies in halos of this or higher mass. The halo occupation properties inferred from the clustering data of Chandra AGNs -- the mass scale of the parent dark matter halos, the lack of significant redshift evolution of the clustering length, and the low satellite fraction -- are broadly consistent with the scenario of quasar activity triggered by mergers of similarly-sized galaxies.

524.07 – **A Survey Of [CII] And Oxygen At z~1-2**

Drew Brisbin[1], G. Stacey[1], C. Ferkinhoff[1], S. Hailey-Dunsheath[1], H. Spoon[1], T. Nikola[1]

[1]*Cornell University*.

9:00 AM - 2:00 PM

We are using our ZEUS spectrometer on the 10.4m CSO to conduct a redshift 1-2 survey of star formation in galaxies using the 158μm [CII] line as our primary probe. The [CII] line is typically the single brightest line from star forming galaxies and is both an important coolant for the ISM and a sensitive probe of the strength of the ambient far-UV field. Using ZEUS, we have now detected the [CII] line from ~24 galaxies. This data is being supplemented with Herschel spectroscopy covering [OI] 63μm, [OIII] 52μm, and [OIV] 26μm, as well as PACS and SPIRE photometry. This ensemble of data constrains the physical conditions of the gas, the strength and hardness of the ambient interstellar radiation fields, and the energy budget of AGN activity in star forming sources. Our previous 13-galaxy survey showed that luminous star forming galaxies in this epoch have moderate intensity kpc-scale star formation - likely an extension of the Schmidt-Kennicutt law to very high gas mass fractions. Our AGN dominated systems have similarly large scale, but significantly more intense star formation suggesting punctuated, collision-induced star formation. Our expanded survey nearly doubles the sample size and also incorporates several known PAH emission sources. The PAH emission arises from PDRs and is related to the photoelectric heating, while the [CII] and [OI] lines trace the cooling. PAHS therefore trace star formation and, since the features are extremely bright, are excellent redshift indicators, which will undoubtedly play a growing role as diagnostic tools in the high-z Universe in the future. Here we present early survey results and discuss the utility of these lines towards unraveling the AGN and star formation activity at high redshifts. We thank NSF and NASA for their support in this work.

524.08 – **First Results from the Spitzer Extended Deep Survey (SEDS)**

Matthew Ashby[1], J. Huang[1], S. P. Willner[1], Z. Wang[1], G. G. Fazio[1], SEDS Team

[1]*SAO*.

9:00 AM - 2:00 PM

The Spitzer Extended Deep Survey (SEDS) is a Cycle 6 Spitzer Exploration survey program (PI Fazio). SEDS is designed to detect the most distant galaxies while controlling for cosmic variance by surveying five premier extragalactic survey fields: COSMOS, the EGS, the UDS, HDFN, and ECDFS. SEDS surveyed a total of 1 square degree in these five fields to a depth of approximately 26 AB mag in both operating bands (3.6 and 4.5 microns) of Spitzer's Infrared Array Camera (IRAC). This contribution describes the survey and presents SEDS source catalogs containing approximately half a million galaxies. It also presents correspondingly deep IRAC source counts and their contribution to the diffuse extragalactic background light (EBL) in the mid-infrared regime. 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.

524.09 – **Constraining SNe Enrichment Using X-ray Observations of Clusters of Galaxies**

G. Esra Bulbul[1], R. Smith[1], M. Lowenstein[2]

[1]*Center for Astrophysics,* [2]*NASA/GSFC*.

9:00 AM - 2:00 PM

X-ray spectroscopy yields accurate measurements of metal enrichment in the intra-cluster medium (ICM). The large reservoir of metals in clusters of galaxies provides a unique way to probe the total number and fraction of supernovae (SNe) types that enrich the ICM integrated over the cluster life-time by directly modeling high spectral resolution X-ray observations using various nucleosynthesis models. The XSPEC model, snapec, offering the possibility to use these vast reservoir of metals in clusters of galaxies to probe the supernovae rates and thereby test the SNe type Ia progenitor models. We will present the evolution of SNe type Ia rate obtained from the XMM-Newton observations of clusters of galaxies to constrain the possible SNe type Ia progenitors.

524.1 – **Establishing New Black Hole Mass Estimators of Active Galactic Nuclei with Hydrogen Paschen lines**

Dohyeong Kim[1], M. Im[1], M. Kim[2]

[1]*Seoul National University, Korea, Republic of,* [2]*National Radio Astronomy Observatory*.

9:00 AM - 2:00 PM

More than 50% of active galactic nuclei (AGNs) are suspected to be red and obscured by dust. Meanwhile, popular spectral diagnostics of AGNs are based on optical or UV light, making dust obscuration the primary concern for

understanding the intrinsic nature of AGNs and the supermassive black holes residing in them. In order to provide a method for estimating properties of dusty red AGNs, we establish new black hole (BH) mass estimators based on near-infrared (NIR) hydrogen emission lines such as Pa and Pb. To establish the BH mass estimators, we used a sample of 37 unobscured type 1 AGNs with an BH mass range of 10^6.8 -- 10^9.4 solar mass, where BH mass comes from either the reverberation mapping method or single-epoch method based on Balmer lines. We show that BH mass can be estimated from the Paschen line luminosities and velocity widths to an accuracy of 0.18 -- 0.24 dex (rms scatter). Our work also show that the mean line ratios of the Paschen and Balmer lines are Ha/Pa~9.00, Hb/Pa~2.70, which are consistent with case B recombination under a typical broad line region (BLR) environmental condition. These line ratios can be used as a reference points when investigating the dusty environmental condition of red AGNs' BLR. We expect the future application of the new BH mass estimators on red AGNs for unveiling intrinsic properties.

524.11 – **The Atacama Cosmology Telescope Sunyaev-Zel'dovich Equatorial Galaxy Cluster Sample**

Felipe Menanteau[1], Atacama Cosmology Telescope

[1]*Rutgers University.*
9:00 AM - 2:00 PM

We have reached the era where microwave surveys such as the Atacama Cosmology Telescope (ACT), the South Pole Telescope (SPT) and Planck are reporting the first samples of massive galaxy clusters through the Sunyaev-Zel'dovich (SZ) effect. Here I will introduce a new mass-selected and redshift-independent sample of optically-confirmed galaxy clusters detected by ACT over approximately 300 square-degrees along the celestial equator overlapping the deep optical u,g,r,i and z imaging from SDSS Stripe 82. This work was supported by the U.S. National Science Foundation through awards AST- 0408698 for the ACT project and PHY-0355328, AST-0707731, and PIRE-0507768 (award number OISE-0530095).

524.13 – **High Resolution SZE Measurements Of CLASH Clusters With MUSTANG**

Charles Romero[1], B. Mason[2], T. Mroczkowski[3], S. Dicker[4], A. Young[4], E. Reese[4], M. Devlin[4], P. Korngut[3], C. Sarazin[1], M. Sun[1], Cluster Lensing And Supernova survey with Hubble

[1]*University of Virginia,* [2]*National Radio Astronomy Observatory,* [3]*Jet Propulsion Lab / Caltech,* [4]*University of Pennsylvania.*
9:00 AM - 2:00 PM

Recent results from SZE observations of galaxy clusters with MUSTANG show substructure in many of the clusters observed to date. The MUSTANG instrument is a bolometer array on the 100-meter Green Bank Telescope (GBT) that operates at 90 GHz. MUSTANG's high angular resolution (9") allows us to find substructure in the electron pressure of the intracluster medium (ICM) via the Sunyaev-Zeldovich Effect (SZE). We report results from the Cluster Lensing And Supernova survey with Hubble (CLASH). These clusters already have complementary data from the radio to X-ray. Understanding how substructure, especially in merging clusters, affects scaling relations is essential to a more precise cosmological picture. We also discuss improvements in data reduction, and revisit previously observed clusters.

524.14 – **VIRUS-P Integral Field Spectroscopy of NGC 3310**

Kathryn E. Powell[1], R. J. Dufour[1], K. B. Kwitter[2], P. Robertson[3]

[1]*Rice University,* [2]*Williams College,* [3]*University of Texas.*
9:00 AM - 2:00 PM

We present the results of spectrophotometric mapping of the SAB(r)bc galaxy NGC 3310 using the VIRUS-P integral field spectrograph on the 2.7m Harlan Smith Telescope at McDonald Observatory (Hill et al. 2008 Proc. SPIE, 7014, 701470). VIRUS-P has an IFU consisting of 246 fibers arranged in an array covering a 2.82 arcmin square FOV with each fiber covering a 4.16 arcsec diameter region. The fibers have a 1/3 filling factor so the observations were dithered with alternating object-sky integrations. The FOV essentially covered the entire visible disk of NGC 3310, enabling a spatial study of the H II regions and stellar properties. Two grating tilts were used, resulting in spectra covering 3400-5600 A and 4600-6800 A with 5 A resolution. The spectra were combined, sky subtracted, and calibrated using the photometric standard star HZ44. We produced an integrated spectrum of the galaxy, which we compare with that from a study of NGC 628 with a similar instrument by Sanchez et al. (2011 MNRAS, 410, 313). We also present an analysis of radial variations in diagnostic emission line ratios of the H II regions such as [O III]5007/Hbeta (excitation), [N II]6583/Halpha, [S II]6717/6730 (electron density), and Halpha/Hbeta (reddening) among others. Since VIRUS-P obtained spectra of the stellar population adjacent to the H II regions, we can partially subtract the underlying stellar continua Balmer line absorption to improve the true Halpha/Hbeta ratio in the nebulae that is useful for mapping the radial variation in reddening and dust content. We also analyzed the radial variation in various emission lines in the H II regions to assess abundance gradients. This research is supported in part by a Rice University undergraduate research grant to K. Powell. We also express gratitude to McDonald Observatory, University of Texas at Austin, for a generous allotment of observing time.

524.15 – **Gamma-Ray Bursts in Circumstellar Shells: A Possible Explanation for Flares**

Robert Mesler[1], D. J. Whalen[2], N. M. Lloyd-Ronning[2], C. L. Fryer[2], Y. M. Pihlstrom[1]

[1]*Unversity of New Mexico,* [2]*Los Alamos National Laboratory.*
9:00 AM - 2:00 PM

It is now generally accepted that long-duration gamma-ray bursts (GRBs) are due to the collapse of massive rotating stars. The precise collapse process itself, however, is not yet fully understood. Strong winds, outbursts, and intense ionizing UV radiation from single stars or strongly interacting binaries are expected to destroy the molecular cloud cores that give birth to them and create highly complex circumburst environments for the explosion. Such environments might imprint features on GRB light curves that uniquely identify the nature of the progenitor and its collapse. We have performed numerical simulations of realistic environments for a variety of long-duration GRB progenitors with ZEUS-MP and have developed an analytical method for calculating detailed GRB light curves in these profiles. We find that, in the context of the standard afterglow model, massive shells around GRBs produce strong signatures in their light curves, and that this clearly distinguishes them from those occurring in uniform media or steady winds. These features can constrain the mass of the shell and the properties of the wind before and after the ejection. Moreover, the interaction of the GRB with the circumburst shell is seen to produce features that are consistent with observed X-ray flares that are often attributed to delayed energy injection by the central engine. Our algorithm for computing light curves is also applicable to GRBs in a variety of environments such as those in high-redshift cosmological halos or protogalaxies, both of which will soon be targets of future surveys such as JANUS or Lobster.

524.16 – **Why Do Galaxies Keep Their Form, But Clusters Of Galaxies Do Not?**

John Perry Cumalat[1], D. F. Bartlett[1]

[1]*University of Colorado, Boulder.*
9:00 AM - 2:00 PM

The Cosinusoidal Potential provides an explanation for the non-observation of dark matter in galaxies. Yet, a mystery remains as to why galaxies combine together to form clusters and superclusters. The galactic velocities are too large to remain gravitationally bound by mutual attraction, so there must be some additional attractive force. The other hint is that clusters of galaxies contain significant amount of hot interstellar gas and ions. Chibisov discussed the effects of a non-zero mass photon that leads to long-range negative pressure. Clusters of galaxies may be bound by magnetic fields alleviating any need for dark matter.

524.17 – **The Luminosity Profile And Structural Parameters Of M31 (Andromeda Galaxy)**

Stephane Courteau[1], L. Widrow[1], M. McDonald[2], P. Guhathakurta[3], Y. Zhu[4], R. L. Beaton[5], S. R. Majewski[5]

[1]*Queen's University, Canada,* [2]*MIT,* [3]*UCSC,* [4]*Harvard University,* [5]*University of Virginia.*
9:00 AM - 2:00 PM

We present the most extended luminosity profile for m31, and its decomposition into a bulge, disk and halo. We apply and address the limitations of different decomposition methods (frequentist vs bayesian) for the 1D luminosity profiles and 2D images. The nucleus, bulge, disk, and halo each contribute 0.05%, 23%, 73% and 4% of the total light of M31 out to 200kpc along the minor axis. Data/model comparisons suggest that the inner regions (R<20-25kpc) of M31 would contain both accreted and in situ stellar populations while the outer regions (R>25-30kpc) may have assembled through pure accretion and satellite disruptions.

This work [Courteau etal 2011, ApJ, 739, 20] was supported by NSERC, NASA, and the NSF.

524.18 – **Enhanced Star Formation In The Abell 2199 Supercluster Based On Wise**

Gwang-Ho Lee[1], M. Lee[1]

[1]*Seoul National University, Korea, Republic of.*
9:00 AM - 2:00 PM

We investigate infrared properties of galaxies located in the entire region (~ 140 deg^2) of the A2199 supercluster (z=0.03) using Wide-field Infrared Survey Explorer (*WISE*) data. The A2199 supercluster is composed of three clusters and several infalling groups. Thanks to a high-density environment and complex structures around A2199, this supercluster is an excellent laboratory for studying the environmental effect on galaxy evolution. *WISE* [3.4]−[12] color is an useful indicator for dividing galaxies into three classes at different evolutionary stages: strong mid-infrared (MIR)-excess ([3.4] − [12] ≥ 3.0) galaxies that are dominated by star-forming galaxies; intermediate MIR-excess (1.0 ≤ [3.4]−[12] < 3.0) galaxies with intermediate stellar ages, and with a small star formation rate (SFR), implying that they are likely to be in transition stages from star-forming galaxies to quiescent galaxies; and weak MIR-excess ([3.4] − [12] < 1.0) galaxies that are passively evolving galaxies with old stellar populations. Weak MIR-excess galaxies prefer high-density regions, whereas strong MIR-excess galaxies are mainly located in low-density regions. The fraction of intermediate MIR-excess galaxies increases with local galaxy density, implying that environment affects the galaxy transition. We derive specific SFRs of clusters (A2199, A2197E/W) and groups (NRGs385, NRGs388, NRGs396, NGC 6159). We find that the specific SFRs of clusters are comparable to or slightly higher than those of groups. This is contrast to a common idea that more massive galaxy systems (i.e. clusters) tend to have lower specific SFRs than less mass systems (i.e. groups). This result suggests that SFRs of clusters are enhanced by close interactions between A2199 and A2197E/W.

524.19 – **An HI and Optical Study of Interacting Galaxies NGC 672 and IC**

1727

Sara Stanchfield[1], E. Wilcots[1], M. Prescott[2]
[1]*UW Madison,* [2]*UC Santa Barbara.*
9:00 AM - 2:00 PM

We present VLA HI radio data and WIYN broadband optical observations of NGC 672 and IC 1727, two nearby, late-type, spiral galaxies. In the optical NGC 672 appears as a symmetric barred spiral with defined spiral arms and a scale length of 1.2 kpc. IC 1727 is asymmetric, lacks a true bar, and has a scale length of 2. 4 kpc. In the HI, we see tidal bridge, indicating interaction between the two galaxies. We map the distribution and kinematics of the neutral hydrogen gas in order to understand the nature of the true distribution of mass in these systems and present the resulting mass models.

524.2 – **Constraining the Metallicity and Escape Fraction of Two z≈3.1 Lyman-Alpha Emitting Galaxies**

Mark L. A. Richardson[1], E. M. McLinden[1], S. Malhotra[1], J. E. Rhoads[1], E. M. Levesque[2]
[1]*Arizona State University,* [2]*University of Colorado at Boulder.*
9:00 AM - 2:00 PM

We observed two z≈3.1 Lyman-α emitting galaxies (LAE) using the Near-infrared Integral Field Spectrometer (NIFS) at Gemini North, specifically looking for [OIII] 4960 & 5008Å, [OII] 3727Å, and H-β 4863Å. We detected the [OIII] doublet in both objects, determined upper limits for [OII] for both objects, and determined upper limits for H-β for one object. With the detections and upper limits we use the [OIII]/[OII] and R23 line diagnostic to attempt to constrain the metallicity and escape fraction of Ly-α. These metallicity constraints are needed to explore the behaviour of the Mass-Metallicty relation in the low-mass regime and also give insight into the star formation histories of LAE which are known to host young stellar populations. The escape fraction, when combined with an extinction correction, gives insight into the presence of neutral gas. This neutral gas is responsible for resonantly scattering any escaped Ly-α photons, increasing its optical depth to dust. For one object we constrain the metallicity to be Z≤ 0.4Z⊙ and constrain the escape fraction of Ly-α to be Fesc ≤ 30%. For the second object we are only able to constrain its escape fraction, finding 6% ≤ Fesc ≤ 40%. We would like to thank the Natural Sciences and Engineering Research Council of Canada for their financial support through a post-graduate fellowship.

524.21 – **The AGN Fraction in the Local Universe**

Edward C. Moran[1], K. Shahinyan[2]
[1]*Wesleyan Univ.,* [2]*Univ. Minnesota.*
9:00 AM - 2:00 PM

We have estimated the AGN fraction in nearby galaxies as a function of host-galaxy luminosity. This work is based on analysis of the nuclear emission-line spectra of all objects within 80 Mpc that were included in the Sloan Digital Sky Survey (SDSS). Our distance-limited selection process has yielded a parent sample that is dominated by low-luminosity, low-mass galaxies for which the AGN fraction is poorly constrained. Our results, which have been corrected for incompleteness in the SDSS, are compiled separately for Seyfert galaxies, LINERs, and "composite" objects that exhibit evidence for both AGN and star-forming activity. Overall, we observe an increase in the AGN fraction with increasing host-galaxy luminosity, suggesting that active black holes in the centers of dwarf galaxies are intrinsically rare. Our results represent a first step toward setting limits on the present-epoch black-hole occupation fraction in galaxies, which could ultimately shed light on the origin of massive black hole seeds at earlier times.

524.22 – **Herschel Pacs Spectroscopy Of Stephan's Quintet: Extreme C+/pah Ratio In The Shocked Gas**

Philip N. Appleton[1], P. Guillard[1], M. Cluver[2], F. Boulanger[3], P. Ogle[1], E. Strurm[4], Herschel OT1_pappleto_1 Team
[1]*Caltech,* [2]*AAO, Australia,* [3]*IAS, France,* [4]*MPE, Germany.*
9:00 AM - 2:00 PM

Spectroscopy observations of the giant shocked filament in Stephan's Quintet by the Spitzer Space Telescope revealed powerful emission from warm molecular hydrogen lines which dominated the line cooling in the mid-IR, and were too powerful to have been formed in PDRs. Our team has now performed Herschel PACS spectroscopy of the shock, and has found, 1) extremely large ratios of C+/PAH > 1 in regions throughout the shock inconsistent with photoelectric heating, and 2) weak or undetected [OI]63 micron and H$_2$O line emission. Contrary to initial expectations that shock-driven C+ would be weak in galaxy-scale shocks, the results suggest that a huge network of low-velocity magnetic C-shocks in a highly turbulent medium is responsible for both the C+ and the warm H$_2$ emission. The results may have implications for the interpretation of molecular and C+ emission from high-z galaxies if turbulence and low-velocity shocks dissipate energy as gas accretes onto DM halos.

524.23 – **The Mildly Non-Linear Regime of Structure Formation**

Svetlin V. Tassev[1], M. Zaldarriaga[2]
[1]*Harvard University,* [2]*Institute for Advanced Study.*
9:00 AM - 2:00 PM

We obtain approximations for the Cold Dark Matter (CDM) particle trajectories starting from Lagrangian Perturbation Theory. These estimates for the CDM trajectories result in approximations for the density in real and redshift space, as well as for the momentum density that are better than what standard Eulerian and Lagrangian perturbation theory give. For the real-space density, we find that our proposed approximation gives a good cross-correlation (>95%) with the non-linear density down to scales almost twice smaller than the non-linear scale, and six times smaller than the corresponding scale obtained using linear theory. This allows building estimators for the matter power spectrum, which are only slightly affected by sample variance, thus allowing for a speed-up of an order of magnitude or more in the scanning of the cosmological parameter space with N-body simulations for the scales relevant for the Baryon Acoustic Oscillations (BAO). Based on our approximations, we develop a quasi-optimal baryon acoustic peak reconstruction method, which markedly improves the sharpening of the BAO peak when compared with standard reconstruction. Other possible future applications of our method include building mock galaxy catalogs, momentum field reconstruction.

525 – Extrasolar Planets, the Solar System and Other Topics

Poster Session – Exhibit Hall, Dena'ina Center – 6/14/2012 9:00:00 AM to 6/14/2012 2:00:00 PM

525.01 – **Transit Model Fitting in the Kepler Science Operations Center Pipeline**

Jie Li[1], C. J. Burke[1], J. M. Jenkins[1], E. V. Quintana[1], J. F. Rowe[1], S. E. Seader[1], P. Tenenbaum[1], J. D. Twicken[1]
[1]*SETI Institute/NASA Ames Research Center.*
9:00 AM - 2:00 PM

We describe the algorithm and performance of the transit model fitting of the Kepler Science Operations Center (SOC) Pipeline. Light curves of long cadence targets are subjected to the Transiting Planet Search (TPS) component of the Kepler SOC Pipeline. Those targets for which a Threshold Crossing Event (TCE) is generated in the transit search are subsequently processed in the Data Validation (DV) component. The light curves may span one or more Kepler observing quarters, and data may not be available for any given target in all quarters. Transit model parameters are fitted in DV to transit-like signatures in the light curves of target stars with TCEs. The fitted parameters are used to generate a predicted light curve based on the transit model. The residual flux time series of the target star, with the predicted light curve removed, is fed back to TPS to search for additional TCEs. The iterative process of transit model fitting and transiting planet search continues until no TCE is generated from the residual flux time series or a planet candidate limit is reached. The transit model includes five parameters to be fitted: transit epoch time (i.e. central time of first transit), orbital period, impact parameter, ratio of planet radius to star radius and ratio of semi-major axis to star radius. The initial values of the fit parameters are determined from the TCE values provided by TPS. A limb darkening model is included in the transit model to generate the predicted light curve. The transit model fitting results are used in the diagnostic tests in DV, such as the centroid motion test, eclipsing binary discrimination tests, etc., which helps to validate planet candidates and identify false positive detections. Funding for the Kepler Mission has been provided by the NASA Science Mission Directorate.

525.02 – **On the Relationship Between a High-frequency Type II Solar Radio Burst and Coronal Mass Ejection on February 13, 2011**

Kyung-Suk Cho[1], N. Gopalswamy[2], R. Kwon[3], R. Kim[3], S. Yashiro[3]
[1]*KASI, NASA/GSFC & CUA,* [2]*NASA/GSFC,* [3]*NASA/GSFC & CUA.*
9:00 AM - 2:00 PM

We examine the relationship between a metric type II radio burst that started from an unusually high frequency of 425 MHz (fundamental component) and the associated white-light coronal mass ejection on 2011 February 11. The radio burst had a drift rate of 3 MHz/sec, indicating a relatively high shock speed. The question we would like to answer is whether the high frequency type II burst is generated by the CME. To avoid the ambiguity normally caused by the use of density models in the analysis of type II bursts, we measure the coronal electron density by applying automated emission measure analysis code developed by Aschwanden et al. (2011) to AIA/SDO images in 6 coronal filters. From SDO AIA observations we find that a loop-like erupting front sweeps across high density coronal loops near the start time of the burst (17:34:15 UT). The deduced height of shock formation (1.2 Rs) from the measured density is comparable to the height (1.15 Rs) of the CME observed by STEREO/EUVI. Thus we conclude that the high frequency type II burst could be generated at locations where the CME passes through the high density loops in the low corona.

525.03 – **Radiogenic heating in exoplanet systems**

Bryce Carande[1], P. Young[1], A. McNamara[1]
[1]*Arizona State University.*
9:00 AM - 2:00 PM

We study the effect of variations in the amount of radiogenic heating on the long-term thermal histories of exoplanets. The amount of radiogenic heating experienced by a planet is dependent on the abundance of long-lived radioisotopes (^{235}U, ^{238}U, ^{232}Th, ^{40}K) present in that stellar system. We explain a method to constrain the uranium abundance of stellar systems using more readily obtained measurements of europium absorption lines in the host star, and present results from a preliminary set of stars (including confirmed exoplanet hosts). We then use a parameterized convection model to simulate the thermal evolution of planetary mantles, given this variation in the abundance of radioisotopes between systems. Our parameterized convection model is based on the boundary layer theory, and includes a crustal heat flow parameter as well as the assumption of a critical Rayleigh number needed for convection. The simulated thermal evolution of a

planet is found to depend more on the choice of heat-flow parameters, and less on the amount of radiogenic heating.

525.04 – **Habitability In Close Binary Systems: Conditions For An Earth-Analogue**

Paul A. Mason[1], J. M. Clark[1]

[1]*New Mexico State University.*

9:00 AM - 2:00 PM

Thanks to the Kepler telescope, and other efforts, the number of known exoplanets has dramatically increased. Detections include planets in binary star systems. The presence of a planet in the habitable zone of a star, or a binary star, is a necessary but not sufficient condition for complex life; which may be quite restrictive, e.g. Ward and Brownlee (2000). Some factors that may make life rare are specific to the planet including the right mass, composition, rotation rate, eccentricity, and axial tilt. Others may be thought of as external factors: intensity and spectrum of stellar radiation, presence in a suitable region of the galaxy, and a stabilizing tidal force. Especially important Earth-Analogue factors appear to include the need for a strong tidal effect and the grand paradox of water in the habitable zone. We generate an ensemble of Earth-analogue planets in P-type close binaries, using random stellar masses, binary semi-major axis, and binary eccentricity. Binaries are selected that provide both a minimally varying radiation flux and a time averaged tidal force, in the HZ, similar to Earth's. When the flux variability is restricted to no more than 6 percent, solutions are found reproducing the time averaged tidal force experienced by Earth. The binaries that met these requirements had a mass ratio greater than 0.8. The ideal minimum flux variability solution is a pair of (nearly) identical early-K stars (near 4900 K) in a circular orbit with a = 0.045 AU, and a planet at 0.93 AU. Next we determine if the time dependent tidal force the Earth experiences can be approximated. These solutions involve binary eccentricities near 0.4 and significant flux variability. We argue that the long life-times of K-stars, and low UV radiation, may provide a niche for complex life.

525.05 – **Finding Kepler's Exoearths**

Erik Petigura[1], G. Marcy[1]

[1]*UC Berkeley.*

9:00 AM - 2:00 PM

With its unprecedented photometric precision and duty cycle, the Kepler mission offers the first opportunity to detect Earth analog planets. Detecting transits with depths of ~0.01%, periods of ~1 year, and durations of ~10 hours pose a novel challenge, prompting an optimization of both the detrending of the photometry and of the transit search algorithm. We present TERRA, the Transiting Exoearth Robust Reduction Algorithm, designed specifically to find earth analogs. TERRA carefully treats systematic effects with timescales comparable to an exoearth transit and removes features that are not important from the perspective of transit detection. We demonstrate TERRA's detection power through an extensive transit injection and recovery experiment.

525.06 – **Determining Exoplanetary Mass From Atmospheric Transmission**

Patricia A. Carroll[1]

[1]*University of Washington.*

9:00 AM - 2:00 PM

Mass measurements of exoplanets traditionally come from radial velocity measurements. In cases where radial velocity measurements are poor, difficult, or unobtainable, we explore an alternative method for estimating the planetary mass using transit measurements of radius as a function of wavelength. Lecavelier Des Etangs et al (2008) find Rayleigh scattering to most likely be the dominant source of near-to-mid-IR extinction in the atmosphere of hot Jupiter HD 189733b. If we assume isothermality, the atmospheric scale height can be directly inferred from the transmission spectrum. The mass of the planet is then derived from the scale height, given estimates of the temperature, surface gravity, and composition. We test this method on well-studied exoplanets HD 189733b and HD 209458b with promising results, and explore possible cases in which this may be the preferred method of exoplanetary mass estimation.

525.07 – **The Journey of Sungrazing Comet Lovejoy**

Paul Bryans[1], M. A'Hearn[2], K. Battams[3], D. Biesecker[4], D. Bodewits[2], D. Boice[5], J. Brown[6], A. Caspi[7], P. Chodas[8], H. Hudson[9], Y. Jia[10], G. Jones[11], H. U. Keller[12], M. Knight[13], J. Linker[14], C. Lisse[15], W. Liu[16], S. McIntosh[17], W. D. Pesnell[1], J. Raymond[18], S. Saar[18], P. Saint-Hilaire[9], C. Schrijver[19], M. Snow[7], T. Tarbell[19], W. Thompson[1], P. Weissman[8], Comet Lovejoy Collaboration Team

[1]*NASA Goddard Space Flight Center,* [2]*Univ. Maryland,* [3]*NRL,* [4]*NOAA,* [5]*SWRI,* [6]*Univ. Glasgow, United Kingdom,* [7]*LASP/CU,* [8]*JPL,* [9]*UC Berkeley,* [10]*UCLA,* [11]*MSSL/UCL, United Kingdom,* [12]*Max Planck Institute for Solar System Research, Germany,* [13]*Lowell Observatory,* [14]*Predictive Science Inc.,* [15]*Johns Hopkins,* [16]*Lockheed Martin/Stanford,* [17]*UCAR,* [18]*Harvard,* [19]*Lockheed Martin.*

9:00 AM - 2:00 PM

Comet Lovejoy (C/2011 W3) was the first sungrazing comet, observed by space-based instruments, to survive perihelion passage. First observed by ground-based telescopes several weeks prior to perihelion, its journey towards the Sun was subsequently recorded by several solar observatories, before being observed in the weeks after perihelion by a further array of space- and ground-based instruments. Such a surfeit of wide-ranging observations provides an unprecedented insight into both sungrazing comets themselves, and the solar atmosphere through which they pass. This paper will summarize what we have learnt from the observations thus far and offer some thoughts on what future sungrazing comets may reveal about comets, the Sun, and their interaction.

525.08 – **The Astronomy Workshop**

Douglas P. Hamilton[1]

[1]*Univ. of Maryland.*

9:00 AM - 2:00 PM

{f The Astronomy Workshop} (http://janus.astro.umd.edu) is a collection of interactive online educational tools developed for use by students, educators, professional astronomers, and the general public. The more than 20 tools in the Astronomy workshop are rated for ease-of-use, and have been extensively tested in large university survey courses as well as more specialized classes for undergraduate majors and graduate students. Here we briefly describe a few of the available tools. {f Solar Systems Visualizer}: The orbital motions of planets, moons, and asteroids in the Solar System as well as many of the planets in exoplanetary systems are animated at their correct relative speeds in accurate to-scale drawings. Zoom in from the chaotic outer satellite systems of the giant planets all the way to their innermost ring systems. {f Solar System Calculators}: These tools calculate a user-defined mathematical expression simultaneously for all of the Solar System's planets (Planetary Calculator) or moons (Satellite Calculator). Key physical and orbital data are automatically accessed as needed. {f Stellar Evolution}: The "Life of the Sun" tool animates the history of the Sun as a movie, showing students how the size and color of our star has evolved and will evolve over billions of years. In "Star Race," the user selects two stars of different masses and watches their evolution in a split-screeen format that emphasizes the great differences in stellar lifetimes and fates.