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Satellite Galaxies in the Illustris-1 Simulation: Poor Tracers of the Underlying Mass Distribution

The 3-d spatial distribution of luminous satellite galaxies in the $z=0$ snapshot of the Illustris-1 simulation is compared to the 3-d spatial distribution of the mass surrounding the primary galaxies about which the satellites orbit. The primary-satellite sample is selected in such a way that it matches the selection criteria used in a previous study of luminous satellite galaxies in the Millennium Run simulation. A key difference between the two simulations is that luminous galaxies in the Millennium Run are the result of a semi-analytic galaxy formation model, while in Illustris-1 the luminous galaxies are the result of numerical hydrodynamics, star formation and feedback models. The sample consists of 1,025 primary galaxies with absolute magnitudes $M_r < -20.5$, and there are a total of 4,546 satellites with absolute magnitudes $M_r < -14.5$ within the virial radii of the primary galaxies. The mass distribution surrounding the primary galaxies is well fitted by an NFW profile with a concentration parameter $c = 11.9$. Contrary to a previous study using satellite galaxies in the Millennium Run, the number density profile of the full satellite sample from Illustris-1 is not at all well-fitted by an NFW profile. In the case of the faintest satellites ($M_r > -17$), the satellite number density profile is well-fitted by an NFW profile, but the concentration parameter is exceptionally low ($c = 1.8$) compared to the concentration parameter of the mass surrounding the primary galaxies. The conclusion from this work is that luminous satellite galaxies in Illustris-1 are poor tracers of the mass distribution surrounding their primary galaxies.

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Probing gravity theory and cosmic acceleration using (in)consistency tests between cosmological data sets

Testing general relativity at cosmological scales and probing the cause of cosmic acceleration are among important objectives targeted by incoming and future astronomical surveys and experiments. I present our recent results on (in)consistency tests that can provide insights about the underlying gravity theory and cosmic acceleration using cosmological data sets. We use new statistical measures that can detect discordances between data sets when present. We use an algorithmic procedure based on these new measures that is able to identify in some cases whether an inconsistency is due to problems related to systematic effects in the data or to the underlying model. Some recent published tensions between data sets are also examined using our formalism, including the Hubble constant measurements, Planck and Large-Scale-Structure. (Work supported in part by NSF under Grant No. AST-1517768).

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Spacetime Dynamics and Slow Neutrino Background

Space is a form of existence of matter, while time is a measure of change of the matter in the space. Isaac Newton suggested that the space and time are absolute, not affected by matter and its motion. His first law of motion or the law of inertia says that, without net force acts on it, an object in motion remains the motion in a straight line at a constant speed. Ernest Mach proposed that the inertia of a body results from the gravitational interaction on the body by the rest of the entire universe. As mass is a measure of inertia, Mach's principle can be simply stated as mass here is affected by matter there. On the basis of Mach's principle, Albert Einstein considered the space and time to be relative and developed two theories of relativities. One called special relativity describes the effect of motion on spacetime and the other called general relativity describes the effect of matter on spacetime. Recently, the author has further considered reactions of the influenced spacetime on the moving objects, including photons. A moving object including a photon, because of its continuously keeping on displacement, disturbs the rest of the entire universe or distorts/cures the spacetime. The distorted or curved spacetime then generates an effective gravitational force to act back on the moving object or photon, so that reduces the object inertia or photon frequency. Considering the disturbance of spacetime by a photon is extremely weak, the author has modelled the effective gravitational force to be Newtonian and derived a new redshift–distance relation that not only perfectly explained the redshift–distance measurement of distant type Ia supernovae but also inherently obtained Hubble's law as an approximate at small redshift. In this study, we will further analyse the reaction of the influenced spacetime on moving neutrinos and demonstrate the creation of slow neutrino (or tired neutrino) background that may be gravitationally orbiting around clusters, galaxies, and any celestial objects to play a role of dark matter in explaining the excess of galactic and clustery rotations. This work was supported by NSF/REU (Grant #: PHY-1559870) at Alabama A & M University.

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The Cosmic Twilight Polarimeter: A Model-Independent Approach to Measure the Sky-averaged Foreground Spectrum for Global 21-cm Cosmology

Detecting the cosmological sky-averaged (global) 21 cm spectrum as a function of observed frequency will provide a powerful tool to study the ionization and thermal history of intergalactic medium (IGM) in the high-redshift Universe (400 million years after the Big Bang). The biggest challenge in conventional ground-based total-power global 21 cm experiments is the removal of the Galactic and extragalactic synchrotron foreground (1E4-1E5 K) to uncover the weak cosmological signal (10-100 mK) due to corruptions on the spectral smoothness of foreground spectrum by instrumental effects. Although an absorption profile has been reported recently at 78 MHz in the sky-averaged spectrum by the Experiment to Detect the Global Epoch of Reionization Signature (EDGES) experiment, it is necessary to confirm that the proposed observation is indeed the global 21 cm signal with an independent approach. In this presentation, we propose a new polarimetry-based observational approach that relies on the dynamic characteristics of the foreground emission at the circumpolar region to track and remove the foreground spectrum directly, without relying on any parametric foreground models as in conventional approaches. Due to asymmetry and the Earth's rotation, the projection of the anisotropic foreground sources onto a wide-view antenna pointing at the North Celestial Pole (NCP) can induce a net polarization which varies with time with a unique twice-diurnal periodicity. Different from the zenith-pointing global 21 cm experiments, by using this twice-diurnal signature, the Cosmic Twilight Polarimeter (CTP) is designed to measure and separate the varying foreground from the isotropic
cosmological background simultaneously in the same observation. By combining preliminary results of the proof-of-concept instrument with numerical simulations, we present a detailed evaluation for this technique and its feasibility in conducting an independent global 21 cm measurement in the near future.

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102.05 – Near-Field Cosmology with Low-Mass Galaxies: Constraining the Escape of Radiation from the UV-slopes of Local Galaxies

Low-mass galaxies are thought to play a large role in reionizing the Universe at redshifts, $z > 6$. However, due to limited UV data on low-mass galaxies, the models used to estimate the escape of radiation are poorly constrained. Using theoretical models of radiation transport in dusty galaxies with clumpy gas media, we translate measurements of the UV slopes of a sample of low-mass low-$z$ KISSR galaxies to their escape fraction values in Ly-alpha radiation, fesc (LyA), and in the Ly-continuum, fesc (LyC). These low-mass starforming systems have potentially steep UV slopes, and could provide a much-needed relation between easily measured spectral properties such as UV slope or LyA line properties, and the escape of LyA/LyC radiation. Such a relation could advance studies of primordial star clusters and the underlying physical conditions characterizing early galaxies, one of the target observational goals of the soon-to-be-launched James Webb Space Telescope.

This work was supported by the University of San Francisco Faculty Development Fund, and NSF grant AST-1637539. We thank the Aspen Center for Physics, where some of this work was conducted, and which is supported by National Science Foundation grant PHY-1607611.

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103 – Molecular Clouds, Dust & Star Formation

103.01 – The Magnetic Field Structure of W3(OH)

Situated in the Perseus arm of the Galaxy, the W3 molecular cloud is a high-mass star-forming region with low foreground optical extinction. Near-infrared H- and K-band polarimetric observations of a 10' × 10' field of view of W3 were obtained using the Mimir instrument on the 1.8 m Perkins Telescope. This field of view encompasses W3(OH), a region of OH and H2O masers as well as an HII region. The H-band data were used in conjunction with Spitzer M-band data to map extinction via H-M color excess. In total, 2654 stellar objects were found in the Mimir field of view, of which 1013 had H and M magnitudes with low errors. Using the extinction map and the individual stellar H-M color excess values, 429 stars with polarized signals were found to be background to the molecular cloud. These were useful for mapping the magnetic field structure and estimating the magnetic field strength of the cloud. Mid- to far-infrared (70 - 870 μm) archival Herschel and Planck data were used to map dust extinction at 850 μm and create an H2 column density map. Combined, maps of magnetic field strength and hydrogen column density can be used to infer the ratio of gravitational potential to magnetic potential ($\frac{M}{\Phi}$). Findings are discussed in the context of $\frac{M}{\Phi}$ ratio in models and the stability of high-mass star-forming regions.

This work has been supported by NSF AST14-12269 and NASA NNX15AE51G grants.

Author(s): Adham M El-Batal1, Dan P. Clemens1, Jordan Montgomery1
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103.02 – Multi-wavelength Polarimetry of the GF9-2 YSO

Our new SOFIA/HAWC+ 214 μm polarimetry of the cloud core containing the young stellar object GF9-2 (IRAS 20503+6006, aka L1082C) has been combined with deep near-infrared H- and K-band polarimetry of the cloud's core, obtained with the Mimir instrument. Additionally, Planck 870 μm and published optical polarimetry are included to provide context at larger size scales. We follow the direction and structure of the plane-of-sky magnetic field from the smallest physical scales (~10 arcsec or 4,000 AU) traced by SOFIA/HAWC+ to the Mimir field of view (10 arcmin, or 1.3 pc) and compare the B-field orientation with that of a faint reflection nebula seen in WISE and Spitzer images. The importance, or lack thereof, for the B-field in this naescent star-forming region is assessed through estimates of the Mass-to-Flux ($\Phi$) ratio.

This work has been supported by NSF AST14-12269, NASA NNX15AE51G, and USRA/SOF 04-0014 grants.

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103.03D – Photon-induced Processing of Interstellar Ices in the Laboratory. Focus on Their Non-thermal Desorption.

Some of the processes that take place in the interstellar medium (ISM) can be simulated in laboratories on Earth under astrophysically relevant conditions. For example, the energetic processing of the ice mantles that accrete on top of dust grains in the coldest regions of the ISM, leading to the production of new species and their desorption to the gas phase. In particular, observation of complex organic molecules (COMs) in cold interstellar environments stress the need for not only a solid state formation but also for non-thermal desorption mechanisms that can account for the observed abundances in regions where thermal desorption is inhibited. Laboratory Astrophysics can be used to test different non-thermal desorption processes and extract yields than can be extrapolated to the astrophysical scenario with theoretical models. 0th generation COMs like CH$_3$OH and H$_2$CO can be formed at very low temperatures. In this talk, we present laboratory simulations of the UV photoprocessing of a binary ice mixture composed by water (the main component of astrophysical ices) and methane. Formation of CO, CO$_2$, CH$_3$OH and H$_2$CO was confirmed by IR spectroscopy and subsequent TPD. At the same time, photodesorption of CO and H$_2$CO was detected by means of a Quadrupole Mass Spectrometer, with yields on the order of 10$^{-4}$ and 10$^{-5}$ molecules per incident photon, respectively. In general, photodesorption can take place through a direct mechanism, where the absorbing molecule (or its photofragments) are desorbed; or through an indirect mechanism where the absorbed energy is transferred to a surface molecule which is the one finally desorbing. In the case of photoprocesses, the evolution of the photodesorption yield gives information on the photodesorption mechanism: a constant photodesorption yield is observed when the photoproducts are desorbed right after their formation; while an increasing yield is measured when the photoproducts are desorbed later after energy transfer from another absorbing molecule, allowing to roughly distinguish between different mechanisms.

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103.04 – The Fourth Flight of CHESS: Analysis of Interstellar H$_2$ on the γ Ara Sightline

In this talk, we describe the scientific motivation and technical development of the Colorado High-resolution Echelle Stellar Spectrograph (CHESS) sounding rocket, focusing on the preliminary science results for the fourth launch of the payload (CHESS-4). CHESS is a far ultraviolet rocket-borne instrument designed to study the atomic-to-molecular transitions within translucent cloud regions in the interstellar medium. CHESS-4 launched on 13 April 2018 aboard NASA/CU sounding rocket mission 36-333 UG. The target for this flight was γ Ara, a B1I star that is known to display a variable and equatorially enhanced stellar wind. We present flight results of interstellar molecular hydrogen excitation, including initial measurements of the column density and temperature, on the sightline. These results are compared to previous values that were calculated using the damping wings of low-J H$_2$ absorption features in Copernicus spectra. We also present analogous flight data for the sightline toward δ Sco, finding that the derived column density of the J$^\prime$ = 1 rotational level differs by a factor of ~2 when compared to the previous observations. We discuss the discrepancies between the two measurements and show that the source of the difference is likely due to the opacity of higher rotational levels contributing to the J$^\prime$ = 1 absorption wing, increasing the inferred column density in the previous work.

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Contribution team(s): Nicholas Kruczek

103.05 – First Results on Interstellar Magnetic Fields from the HAWC+ Instrument for SOFIA

HAWC+, a second-generation SOFIA instrument designed to map far-infrared intensity and polarization, was commissioned in late 2016 and made first science observations in SOFIA Cycles 4 and 5. We describe basic characteristics of the instrument, report on the commissioning flights and data analysis pipeline, and show some example science products resulting from Guaranteed-Time Observations (GTO). HAWC+ and SOFIA provide unique access to the far-infrared (50 - 250 micron) spectral range for polarimetry. Far-IR polarization arises from dust grains aligned with respect to the magnetic field, as well as synchrotron radiation, and the GTO program focuses primarily on the magnetic field structure of nearby molecular clouds and the Galactic center, and the physical characteristics of dust.

Author(s): C. Darren Dowell$^1$
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Contribution team(s): HAWC+ Instrument and Science Teams

103.06 – Infrared Spectroscopic Studies of the Properties of Dust in the Ejecta of Galactic Oxygen-Rich Asymptotic Giant Branch Stars

We are conducting a series of infrared studies of large samples of mass-losing asymptotic giant branch (AGB) stars to explore the relationship between the composition of evolved star ejecta and host galaxy metallicity. Our previous studies focused on mass loss from evolved stars in the relatively low-metallicity Large and Small Magellanic Clouds. In our present study, we analyze dust in the mass-losing envelopes of AGB stars in the Galaxy, with special focus on the ejecta of oxygen-rich (O-rich) AGB stars. We have constructed detailed dust opacity models of AGB stars in the Galaxy for which we have infrared spectra from, e.g., the Spitzer Space Telescope Infrared Spectrograph (IRS). This detailed modeling of dust features in IRS spectra informs our choice of dust properties to use in radiative transfer modeling of the broadband SEDs of Bulge AGB stars. We investigate the effects of dust grain composition, size, shape, etc. on the AGB stars’ infrared spectra, studying both the silicate dust and the opacity source(s) commonly attributed to alumina (Al$_2$O$_3$). BAS acknowledges funding from NASA ADAP grant 80NSSC17K0057.

Author(s): Benjamin A. Sargent$^1$, Sundar Srinivasan$^1$, Joel Kastner$^2$, Margaret Meixner$^3$, Allyssa Riley$^3$

103.07 – A Simple Non-equilibrium Model of Star Formation and Scattering in the Kennicutt-Schmidt Relation and Star Formation Efficiencies in Galaxies

I will present a simple model of non-equilibrium star formation and its relation to the scatter in the Kennicutt-Schmidt relation and large-scale star formation efficiencies in galaxies. I will highlight the importance of a hierarchy of timescales, between the galaxy dynamical time, local free-fall time, the delay time of stellar feedback, and temporal overlap in observables, in setting the scatter of the observed star formation rates for a given gas mass. Further, I will talk about how these timescales (and their associated duty-cycles of star formation) influence interpretations of the large-scale star formation efficiency in reasonably star-forming galaxies. Lastly, the connection with galactic centers and out-of-equilibrium feedback conditions will be mentioned.

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104.02 – Early results from HAWC+ / SOFIA

Observation of infall is key to our understanding of the accretion process in star formation. High-resolution spectroscopy allows us to resolve molecular lines originating from the dense molecular envelopes of the forming (proto-) stars to deduce the kinematics of the gas. In this contribution, I’ll describe how SOFIA can significantly contribute to the quest for and characterisation of infall by providing unique access to molecular lines at THz frequencies that allow red-shifted absorption studies as direct probe of infall and that provide access to fine structure and high excitation lines that probe outflowing gas as indirect evidence for accretion. In particular, I will report on a recent study using the GREAT high-spectral resolution instrument on-board of SOFIA to observe ammonia at 1.8 THz. Eight out of eleven observed massive clumps have been found with red-shifted absorption that is indicative of infall motions. This fraction of 72% is substantially higher than that found in past searches for the blue-skewed profile signature. The observations show that infall on clump scales is ubiquitous through a wide range of evolutionary stages.

Author(s): Friedrich Wyrowski
Institution(s): Max Planck Institute for Radio Astronomy

104.03 – The quest for infall in star-forming regions

In the quest for understanding the role of magnetic fields in high mass star formation, including the role that magnetic fields play in each.

Author(s): Judith Pipher
Institution(s): 1. University of Rochester

104.04 – [CII] emission from NGC 4258 with SOFIA/FIFI-LS

We present the [CII]157.7μm map of the NGC 4258 (M106) galaxy obtained with the FIFI-LS spectrometer onboard SOFIA. M106 contains an active nucleus classified as type 1.9 Seyfert with a warped inner rotating disk of water-vapor masers which allowed for the first high accuracy measurements of the mass of a supermassive black hole in any galaxy. A relativistic jet is thought to be responsible for anomalous radio-continuum spiral arms, which appear several kpc from the center, and extend outwards through the outer disk. These arms do not correlate with the galaxy’s outer disk, exciting synchrotron radiation. Since that time, a new burst of activity seems to have occurred, creating a compact jet at the core of the galaxy, and two radio hotspots further out associated with optical "bow-shocks". The position angle of this new "active" jet is different from that needed to excited the outer radio arms, presumably because the jet has precessed, perhaps as a result of precession of the axis of the inner warped accretion disk.

Our observations reveal three main sources of [CII] emission: two associated with large regions of gas at the ends of the active jet, and a third minor axis filament associated with linear clumps of star formation and dust seen in HST images offset from the nucleus. We combine the SOFIA observations with previous Spitzer mid-IR, Chandra X-ray and VLA radio observations to explore the nature of the detected [CII] emission. In regions along the northern active jet, we see a significant deficiency in the [CII]/FIR ratio, and higher ratios near the ends of the jet. This implies that the jet has changed the conditions of the gas along its length. In several places near the jet, the [CII] emission shows very broad lines, suggestive of enhanced turbulence. Additionally, the minor-axis filament we discovered may represent gas inflow towards the nucleus perpendicular to the jet. The results provide clues about how radio jets in active galaxies can influence the star formation properties of their host galaxies.
Spectral Analyses of New Metal-poor Stars

106 – Stellar Abundances in Dwarf Galaxies I: The Origin of Metal-Poor Stars in the Milky Way

106.01 – Introduction

Dwarf galaxies are excellent laboratories of chemical evolution. Many dwarf galaxies have simple star formation histories with very low average star formation rates. These conditions simplify models of chemical evolution and facilitate the identification of sites of nucleosynthesis. Dwarf galaxies also host extremely metal-poor stars, which sample the ejecta of the first generations of supernovae in the universe.

This meeting-in-a-meeting, "Stellar Abundances in Dwarf Galaxies," will recognize the importance of dwarf galaxies in learning about the creation and evolution of the elements. Topics include:

* the most metal-poor stars
* the connection between dwarf galaxies and the Milky Way halo
* dwarf galaxies as the paragons of process nucleosynthesis
* modern techniques in stellar abundance measurements
* recent advances in chemical evolution modeling

I will give a very brief introduction to set the stage for the meeting.

Author(s): Evan N Kirby
Institution(s): 1. California Institute of Technology

106.02 – Pristine Survey : High-Resolution Spectral Analyses of New Metal-poor Stars

The Pristine survey (Starkenburg et al. 2017) is a new and very successful metal-poor star survey. Combining high-quality narrow-band CaHK CFHT/MegaCam photometry with existing broadband photometry from SDSS, then very metal-poor stars have been found as confirmed from low-resolution spectroscopy (Youakim et al. 2017). Furthermore, we have extended this survey towards the Galactic bulge in a pilot program to test the capabilities in the highly crowded and (inhomogeneously) extincted bulge (Arentsen et al. 2018). High resolution spectral follow-up analyses have been initiated at the CFHT with Espadons (V<15) and the Gemini/GRACES long optical fibre that also feeds the Espadons spectrograph (15<V<18) to examine the detailed chemical abundances in the newly found metal-poor stars and to measure precision radial velocities. These spectra are used to search for chemical signatures that can be associated with the early and/or rapid Galactic chemical evolution or changes in the IMF, e.g., carbon enrichment, high [alpha/Fe] ratios vs alpha-challenged stars, and details in the neutron capture element ratios. While these early studies are being carried out using classical model atmospheres and synthetic spectral fitting (Venn et al. 2017, 2018), we are also exploring the use of a neural network for the fast, efficient, and precise determination of these stellar parameters and chemical abundances (e.g., StarNet, Fabbro et al. 2018).
106.03 – Using photometrically selected metal-poor stars to study dwarf galaxies and the Galactic stellar halo
The Pristine survey is a narrow-band photometric survey designed to efficiently search for extremely metal-poor (EMP) stars. In the first three years of the survey, it has demonstrated great efficiency at finding EMP stars, and also great promise for increasing the current, small sample of the most metal-poor stars. The present sky coverage is ~25000 square degrees in the Northern Galactic Halo, including several individual fields targeting dwarf galaxies. By efficiently identifying member stars in the outskirts of known faint dwarf galaxies, the dynamical histories and chemical abundance patterns of these systems can be understood in greater detail. Additionally, with reliable photometric metallicities over a large sky coverage it is possible to perform a large scale clustering analysis in the Milky Way halo, and investigate the characteristic scale of substructure at different metallicities. This can reveal important details about the process of building up the halo through dwarf galaxy accretion, and offer insight into the connection between dwarf galaxies and the Milky Way halo. In this talk I will outline our results on the search for the most pristine stars, with a focus on how we are using this information to advance our understanding of dwarf galaxies and their contribution to the formation of the Galactic stellar halo.

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Contributing team(s): Pristine team

106.04 – Chemical abundances in metal-poor Galactic halo stars
I will provide an update of our high-resolution spectroscopic follow-up of halo metal-poor star candidates from the SkyMapper

107 – AAS Taskforce on Diversity and Inclusion in Astronomy Graduate Education

108 – Plenary Talk: Heavy Element Synthesis in the Universe, Enrico Ramirez-Ruiz (UCO, Lick)
108.01 – Heavy element synthesis in the Universe
The source of about half of the heaviest elements in the Universe has been a mystery for a long time. Although the general picture of element formation is well understood, many questions about the nuclear physics processes and particularly the astrophysical details remain to be answered. Here I focus on recent advances in our understanding of the origin of the heaviest and rarest elements in the Universe.

Author(s): Enrico Ramirez-Ruiz1
Institution(s): 1. University of California, Santa Cruz

110 – Black Holes, Neutron Stars, and Supernovae
110.01 – Making Sense of Black Holes: Modeling the Galactic Center and Other Low-power AGN
The Galactic center host a well-known flat-spectrum radio source, Sgr A*, that is akin to the radio nuclei of quasars and radio galaxies. It is the main target of the Event Horizon Telescope to image the shadow of the black hole. There is, however, still considerable discussion on where the near-horizon emission originates from. Does it come from an accretion flow or is it produced in a relativistic jet-like outflow? Using advanced three-dimensional general relativistic magnetohydrodynamics simulations coupled to general relativistic ray tracing simulations, we now model the dynamics and emission of the plasma around the black hole in great detail out to several thousand Schwarzschild radii. Jets appear almost naturally in these simulations. A crucial parameter is the heating of radiating electrons and we argue that electron-proton coupling is low in the accretion flow and high in the magnetized region of the jets, making the jet an important ingredient for the overall appearance of the source. This comprehensive model is able to predict the radio size and appearance, the spectral energy distribution from radio to X-rays, the variability, and the time lags of Sgr A* surprisingly well. Interestingly, the same model can be easily generalized to other low-power AGN like M87, suggesting that GRMHD models for AGN are finally becoming predictive. With upcoming submm-VLBI experiment on the ground and in space, we will be able to further test these models in great detail and see black holes in action.

Author(s): Heino Falcke1
Institution(s): 1. Radboud University

110.02 – Nebular Phase Spectra of SNe Ia from the CSP2 Sample
We present a comparison of late-time spectra in the near-infrared for some of the Type Ia supernovae from the Carnegie Supernova Project II. Particular attention is paid to the shape and evolution
of several emission features, including the [Fe II] line at 1.6440 μm. We put our findings in context of several explosion scenarios and progenitor systems.

Author(s): Tiara Diamond¹
Institution(s): 1. Goddard Space Flight Center
Contribution team(s): Carnegie Supernova Project II

110.03D – The Chemical Signature of SN Iax in the Stars of Ursa Minor?

Recently, a new class of supernovae Ia was discovered: the supernovae Iax; the increasing sample of these objects share common features as lower maximum-light velocities and typically lower peak magnitudes.

In our scenario, the progenitors of the SNe Iax are very massive white dwarfs, possibly hybrid C+O+Ne white dwarfs; due to the accretion from a binary companion, they reach the Chandrasekhar mass and undergo a central carbon deflagration, but the deflagration is quenched when it reaches the outer O+Ne layer. This class of SNe Ia is expected to be rarer than standard SNe Ia and do not affect the chemical evolution in the solar neighbourhood; however, they have a short delay time and they could influence the evolution of metal-poor systems. Therefore, we have included in a stochastic chemical evolution model for the dwarf spheroidal galaxy Ursa Minor the contribution of SNe Iax.

The model predicts a spread in [Mn/Fe] in the ISM medium at low metallicity and - at the same time - a decrease of the [alpha/Fe] elements, as in the classical time delay model. This is in surprising agreement with the observed abundances in stars of Ursa Minor and provide a strong indication to the origin of this new classes of SN Ia.

Author(s): Gabriele Cescutti¹, Chiaki Kobayashi²
Institution(s): 1. Trieste Observatory, INAF, 2. University of Hertfordshire

110.04 – Physical Conditions in Shocked Interstellar Gas Interacting with the Supernova Remnant IC 443

We present the results of a detailed investigation into the physical conditions in interstellar material interacting with the supernova remnant IC 443. Our analysis is based on an examination of high-resolution HST/STIS spectra of two stars probing predominantly neutral gas located both ahead of and behind the supernova shock front. The pre-shock neutral gas is characterized by densities and temperatures typical of diffuse interstellar clouds, while the post-shock material exhibits a range of more extreme physical conditions, including high temperatures (> 10^4 K) in some cases, which may require a sudden heating event to explain. The ionization level is enhanced in the high-temperature post-shock material, which could be the result of enhanced radiation from shocks or from an increase in cosmic-ray ionization. The gas-phase abundances of refractory elements are also enhanced in the high-pressure gas, suggesting efficient destruction of dust grains by shock sputtering. Observations of highly-ionized species at very high velocity indicate a post-shock temperature of 10^7 K for the hot X-ray emitting plasma of the remnant’s interior, in agreement with studies of thermal X-ray emission from IC 443.

Author(s): Adam M. Ritcey⁴, Steven Robert Federman³, Edward B. Jenkins⁴, Damiano Caprioli², George Wallerstein⁴

111 – Extrasolar Planets

111.01 – Stability of planetary orbits in triple star systems

Triple stellar systems comprising a central binary orbited by a third star at a larger distance are fairly common. However, there have been very few studies on the stability of planetary orbits in such systems. There has been almost no work on generalised systems, little on retrograde planetary orbits and none on retrograde stellar orbits, with nearly all being for coplanar orbits and for a limited number of orbital parameters. We provide a generalised numerical mapping of the regions of planetary stability in triples, using the symplectic N-body code HJS (Beust 2003) designed for the dynamics of multiple hierarchical systems.
We investigate all these orbit types and extend the parameters used to all relevant orbital elements of the triple's stars, also expanding these elements and mass ratios to wider ranges.

This establishes the regions of secular stability and results in empirical models describing the stability bounds for planets in each type of triple configuration, as functions of the various system parameters. These results are compared to the corresponding results for binaries in the limit of a vanishing mass of the third star. A general feature is that retrograde planetary orbits appear more stable than prograde ones, and that stable regions also tend to be wider when the third star's motion is retrograde. Conversely, we point out the destabilizing role of Kozai-Lidov resonance in non-coplanar systems, which shrinks the stability regions as a result of large induced eccentricity variations. Nonetheless, large enough stability regions for planets do exist in triples, and this should motivate future observational campaigns.

Buseti, Beust, Harley, 2018, to be submitted to A&A

Author(s): Franco Busetti, Hervé Beust, Charis Harley Institution(s): 1. Université Grenoble Alpes, 2. University of the Witwatersrand

111.02 – The Ongoing Evolution of the K2-22 System
Of the thousands of exoplanets known, only three disintegrating planets have been identified. These disintegrating planets appear to have tails of dusty material that produce asymmetric transit shapes. K2-22b is one of these few disintegrating planets discovered to date, and its light curve not only displays highly variable transit depths but also uniquely displays evidence of a leading dust tail. Here, we present results from a large ground-based photometric observing campaign of the K2-22 system that took place between December 2016 and May 2017, which we use to investigate the evolution of the transit of K2-22b. Last observed in early 2015, in these new observations we recover the transit around the expected time and measure a typical depth of <1%. We find that the transit depth has decreased compared to observations from 2014 and 2015, where the maximum transit depth measured at that time was ~1.3%. These new observations support ongoing variability in the transit depth, shape, and time of K2-22b, although the overall shallowness of the transit makes a detailed analysis of the transit shape and timing difficult. In addition, we find no strong evidence of wavelength-dependent transit depths for epochs where we have simultaneous coverage at multiple wavelengths. Given the observed decrease in the transit depth between 2015 and 2017, we encourage continued high-precision photometric monitoring of this system in order to further constrain the evolution timescale and to aid comparative studies with the other few disintegrating planets known.

Author(s): Knicole D. Colon, George Zhou, Avi Shporer, Karen A Collins, Allyson Bieryla, David W. Latham, Nestor Espinoza, Felipe Murgas, Petchara Pattarakijwongchi, Supacha Apiwan


Contributing team(s): TECH Collaboration

111.03 – Standardizing Exoplanet Analysis with the Exoplanet Characterization Tool Kit (ExoCTK)
Exoplanet characterization depends critically on analysis tools, models, and spectral libraries that are constantly under development and have no single source nor sense of unified style or methods. The complexity of spectroscopic analysis and initial time commitment required to become competitive is prohibitive to new researchers entering the field, as well as a remaining obstacle for established groups hoping to contribute in a comparable manner to their peers. As a solution, we are developing an open-source, modular data analysis package in Python and a publicly facing web interface including tools that address atmospheric characterization, transit observation planning with JWST, JWST corongraphy simulations, limb darkening, forward modeling, and data reduction, as well as libraries of stellar, planet, and opacity models. The foundation of these software tools and libraries exist within pockets of the exoplanet community, but our project will gather these seedling tools and grow a robust, uniform, and well-maintained exoplanet characterization toolkit.

Author(s): Julia Fowler, Kevin B. Stevenson, Nikole K. Lewis, Jonathan D. Fraine, Laurent Pueyo, Giovanni Bruno, Joe Filippazzo, Matthew Hill, Natasha Batalha, Hannah Wakeford, Rafia Bushra

Institution(s): 1. Space Telescope Science Institute

111.04 – Stellar CME candidates: towards a stellar CME-flare relation
For decades the Sun has been the only star that allowed for direct CME observations. Recently, with the discovery of multiple extrasolar systems, it has become imperative that the role of stellar CMEs be assessed in the context of exoplanetary habitability. Solar CMEs and flares show a higher association with increasing flaring energy, with strong flares corresponding to large and fast CMEs. As argued in earlier studies, extrasolar environments around active stars are potentially dominated by CMEs, as a result of their extreme flaring activity. This has strong implications for the energy budget of the system and the atmospheric erosion of orbiting planets.

Nevertheless, with current instrumentation we are unable to directly observe CMEs in even the closest stars, and thus we have to look for indirect techniques and observational evidence and signatures for the eruption of stellar CMEs. There are three major observational techniques for tracing CME signatures in other stellar systems, namely measuring Type II radio bursts, Doppler shifts in UV/optical lines or transient absorption in the X-ray spectrum. We present observations of the most probable stellar CME candidates captured so far and examine the different observational techniques used together with their levels of uncertainty. Assuming that they were CMEs, we try to assess their kinematic and energetic characteristics and place them in an extension of the well-established solar CME-flare energy scaling law. We finish by discussing future observations for direct measurements.

Author(s): Sofia Paraskevi Moschou

Institution(s): 1. Harvard-Smithsonian CfA

Contributing team(s): Jeremy J. Drake, Ofer Cohen, Julian D. Alvarado-Gomez, Cecilia Garraffo

111.05 – Atmospheres of Two Super-Puffs: Transmission Spectra of Kepler 51b and Kepler 51d
The Kepler 51 system hosts three transiting, extremely low-mass, low-density exoplanets. These planets orbit a young G type star at periods of 45, 85 and 130 days, placing them outside of the regime for the inflated hot-Jupiters. Instead, the Kepler 51 planets are part of a rare class of exoplanets: the super-puffs. Models suggest these H/He-rich planets formed outside of the snow-line and migrated inwards, which might imply abundant water in their atmospheres. Because Kepler 51b and 51d have low surface gravities, they also have scale heights 10x larger than a typical hot-Jupiter, making them prime targets for atmospheric investigation. Kepler 51c, while also possessing a large scale height, only grazes its star during transit. We are also presented with a unique opportunity to study two super-puffs in very different temperature regimes around the same star. Therefore, we observed two transits each of both Kepler 51b and 51d with the Hubble Space Telescope’s Wide Field Camera 3 G141 grism spectroscopy. Using these data we created spectroscopic light curves that allow us to compute a transmission spectrum for each planet. We conclude that both planets have a flat transmission
spectrum with a precision better than 0.6 scale heights between 1.1 and 1.7 microns. We also analyzed the transit timing variations of each planet by combining re-fitted Kepler mid-transit times with our measured HST times. From these additional timing points, we are able to better constrain the planetary masses and the dynamics of the system. With these updated masses and revisited stellar parameters, we determine precise measurements on the densities of these planets. We will present these results as well as discuss the implications for high altitude aerosols in both Kepler 51b and 51d.

### 112 – Infrared Astrophysics in the SOFIA Era II

This session addresses three topics—(1) The Birth of Planets and Stars, (2) The Path to Life, and (3) Extreme Environments— which are scientific objectives for the Stratospheric Observatory for Infrared Astronomy. SOFIA provides access to celestial far-infrared radiation, from above 99% of the water in the Earth’s atmosphere, following the successes of far-infrared-optimized telescopes like IRTF and Gemini and space telescopes like Spitzer and Herschel. Far-infrared observations provide synergy with those in the sub-millimeter by ALMA and in the mid-infrared by JWST. This session will present forward-looking prospects in each topic and to tie them to far-infrared capabilities. SOFIA supports numerous PhD theses and ongoing instrument development, both of which will feature in the session.

#### 112.01 – Future of SOFIA and the Path to Life

**112.02 – The molecular inventory around protostars: water, organic molecules, and the missing oxygen problem**  
Massive star formation is accompanied by significant chemical evolution in the surrounding interstellar gas. Here, grains are heated up and icy mantles evaporate, releasing a rich inventory of water and organic molecules into the gas-phase within “hot core” regions surrounding massive protostars. Because molecules on the grain surface present broad infrared features without rotational structure, only the most abundant molecules can be identified unambiguously in the solid phase; once released into the gas-phase, however, where they are free to rotate, the constituents of grain mantles can be identified easily by means of rotational spectroscopy at millimeter and submillimeter wavelengths or through rovibrational spectroscopy in the mid-infrared. While observations of pure-rotational emission lines provide a broad view of hot core chemistry, absorption line spectroscopy of rovibrational transitions can probe the very hottest material closest to the protostar.

With access to the mid-infrared spectral region from above 99% of Earth’s water vapor, SOFIA provides a unique platform for high-resolution rovibrational spectroscopy of water and organic molecules, many of which have vibrational transitions in the 5 – 8 micron spectral region that is unobservable from the ground. High spectral resolution is essential for disentangling the rotational structure and providing reliable measurements of the molecular column densities and temperatures. Future SOFIA observations will help elucidate the inventory of water and organic molecules around young protostars, and can address a puzzle related to the “oxygen budget” in the interstellar medium: surprisingly, the main interstellar reservoirs of the third-most abundant element in the Universe have yet to be identified.

**Author(s): David A. Neufeld**  
**Institution(s): 1. Johns Hopkins Univ.**

#### 112.03 – Polycyclic Aromatic Hydrocarbon molecules in space

**113 – LAD: Bridging Laboratory & Astrophysics: Disks and Circumstellar Outflows in the ALMA Era**  
Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the macroscopic and microscopic properties of disks and outflows.

#### 113.01 – Protoplanetary disk observations in the ALMA era

In this talk, I’ll discuss how ALMA is advancing our understanding of protoplanetary disks with its unprecedented sensitivity and spatial resolution. In particular, I’ll focus on how ALMA is providing our first detailed view of gas-phase chemistry in giant planet forming regions, allowing us to test our ideas about how planets develop their diverse characteristics. Interpretation of these spectroscopic datasets requires sophisticated modeling tools and accurate laboratory data, as protoplanetary disks are ever-evolving environments that span a large range in density, temperature, and radiation field. I’ll discuss some recent results that highlight the important interplay between modeling and data analysis/interpretation, and suggest research directions that ALMA is likely to pursue going forward.

**Author(s): Colette Salyk**  
**Institution(s): 1. Vassar College**

#### 113.02 – What Governs Ice-Sticking in Planetary Science Experiments?

Water ice plays an important role, alongside dust, in current theories of planet formation. Decades of laboratory experiments have proven that water ice is far stickier in particle collisions than dust. However, water ice is known to be a metastable material. Its physical properties strongly depend on its environmental parameters, the foremost being temperature and pressure. As a result, the properties of ice change not only with the environment it is observed in, but also with its thermal history.

The abundance of ice structures that can be created by different environments likely explains the discrepancies observed across the multitude of collisional laboratory studies in the past [1-16]; unless the ices for such experiments have been prepared in the same way and are collided under the same environmental conditions, these experiments simply do not collide the same ices.

This raises several questions:
1. Which conditions and ice properties are most favourable for ice sticking?
2. Which conditions and ice properties are closest to the ones observed in protoplanetary disks?
3. To what extent do these two regimes overlap?
4. Consequently, which collisional studies are most relevant to planetary science and therefore best suited to inform models of planet formation?

In this presentation, I will give a non-exhaustive overview of what we already know about the properties of ice particles, covering those used in planetary science experiments and those observed in planet forming regions. I will discuss to what extent we can already answer questions 1-3, and what information we still need to obtain from observations, laboratory experiments, and modelling to be able to answer question 4.

References:
2. Bridges et al. 1996 Icar 123.
12. McDonald et al. 1989 Icar 82.

114 – Stellar Abundances in Dwarf Galaxies II: The Most Metal-poor Stars in Dwarf Galaxies

114.01 – What is the Milky Way outer halo made of?
In a framework where galaxies form hierarchically, extended stellar halos are predicted to be an ubiquitous feature around Milky Way-like galaxies and to consist mainly of the shredded stellar component of smaller galactic systems. The type of accreted stellar systems are expected to vary according to the specific accretion and merging history of a given galaxy, and so is the fraction of stars formed in-situ versus accreted. Analysis of the chemical properties of Milky Way halo stars out to large Galactocentric radii can provide important insights into the properties of the environment in which the stars that contributed to the build-up of different regions of the Milky Way stellar halo formed. In this talk I will focus on the outer regions of the Milky Way stellar halo, and present results from a program aimed at determining chemical abundances of halo stars with large present-day Galactocentric distances, >15 kpc. The data-set consists of high resolution spectra for 28 red giant branch stars covering a wide metallicity range. We show that the ratio of $\alpha$-elements over Fe as a function of [Fe/H] for our sample of outer halo stars is not dissimilar from the pattern shown by MW halo stars from solar neighborhood samples. On the other hand, significant differences appear at [Fe/H]$\leq$-1.5$\delta$ when considering chemical abundance ratios such as [Ba/Fe], [Na/Fe], [Ni/Fe], [Eu/Fe], [Ba/Y]. Qualitatively, this type of chemical abundance trends are observed in massive dwarf galaxies, such as Sagittarius and the Large Magellanic Cloud. This appears to suggest a larger contribution in the outer halo of stars formed in an environment with high initial star formation rate and already polluted by asymptotic giant branch stars with respect to inner halo samples.

Author(s): Pascale Jablonka1
Institution(s): 1. EPFL
Contributing team(s): G. Battaglia

114.02 – CEMP Stars in Dwarf Galaxies
Exploration of the metal-poor stellar halo population of the Milky Way over the past decades has revealed a large number of stars strongly enhanced in carbon (CEMP stars). However, these stars are not as commonly detected in the dwarf galaxy satellites of the Milky Way (MW). The present-day satellites are thought to be similar to systems from which the MW and in particular its halo was formed via hierarchical mergers. I will present the results of abundance analysis for new samples of extremely metal-poor stars in Sculptor and Carina exploring the fraction of CEMP stars at low metallicity in these systems. I will also present the detailed abundance analyses of six CEMP stars detected in the Carina dwarf spheroidal galaxy. Five of these stars also show enhancement in slow neutron-capture elements and can thus be classified as CEMP-s stars, while the most metal-poor star with [Fe/H]=-2.5 shows no such enhancement and belongs to the CEMP-no class. The detection of CEMP stars in dwarf galaxies supports the hierarchical assembly of the MW halo and by providing a birth environment, can help to further constrain the formation of these stars.

Author(s): Terese Thidemann Hansen1
Institution(s): 1. Observatories of the Carnegie Institution for Science

114.03 – RR Lyrae stars in and around NGC 6441: signatures of dissolving cluster stars
Detailed elemental abundance patterns of metal-poor ([Fe/H]~ -1.0 dex) stars in the Galactic bulge indicate that a number of them are consistent with globular cluster (GC) stars and may be former members of dissolved GCs. This would indicate that a few per cent of the Galactic bulge was built up from destruction and/or evaporation of globular clusters. Here an attempt is made to identify such presumptive destroyed stars originating from the massive, inner Galaxy globular cluster NGC~6441 using its rich RR Lyrae variable star (RRL) population. We present radial velocities of forty RRLs centered on the globular cluster NGC~6441. All of the 13 RRLs observed within the cluster tidal radius have velocities consistent with cluster membership, with an average radial velocity of $24 \pm 5 \text{km/s}$ and a star-to-star scatter of $11 \text{km/s}$. This includes two new RRLs that were previously not associated with the cluster. Eight RRLs with radial velocities consistent with cluster membership but up to three times the distance from the tidal radius are also reported. These potential extra-tidal RRLs also have exceptionally long periods, which is a curious characteristic of the NGC~6441 RRL population that hosts RRLs with periods longer than seen anywhere else in the Milky Way. As expected of stripped cluster stars, most are inline with the cluster’s orbit. Therefore, either the tidal radius of NGC~6441 is underestimated and/or we are seeing dissolving cluster stars stemming from NGC~6441 that are building up the old spheroidal bulge. Both the mean velocity of the cluster as well as the underlying field population is consistent with belonging to an old spheroidal bulge with low rotation and high velocity dispersion that formed before the bar.

Author(s): Sabrina Gaertner1
Institution(s): 1. STFC/UKRI ISIS Neutron & Muon Source
Contributing team(s): B. Gundlach, J. Blum, H. J. Fraser

113.03 – MRI and Related Astrophysical Instabilities in the Lab
The dynamics of accretion in astronomical disks is only partly understood. Magnetorotational instability (MRI) is surely important but has been studied largely through linear analysis and numerical simulations rather than experiments. Also, it is unclear whether MRI is effective in protostellar disks, which are likely poor electrical conductors. Shear-driven hydrodynamic turbulence is very familiar in terrestrial flows, but simulations indicate that it is inhibited in disks. I summarize experimental progress and challenges relevant to both types of instability.

Author(s): Jeremy Goodman1
Institution(s): 1. Princeton Univ. Obs.
114.04 – A window on first-stars models from studies of dwarf galaxies and galactic halo stars

Dwarf galaxies dominate the local universe by number and are predicted to be even more dominant at early times, with many having large star formation rates per unit mass. The cosmological role of dwarf galaxies in the metal enrichment and the reionization of the universe is an important but unresolved problem at present. Nearby low-mass galaxies are much more accessible observationally for detailed study and may be local analogs of the types of galaxies that hosted the first-light sources relevant for reionization. I will share recent results on UV studies of the escaping radiation from nearby low-mass starforming galaxies, as well as the tantalizing similarities in element abundance patterns between local dwarf galaxies and the latest data compilations on extremely metal-poor stars in galactic halos. I will highlight trends of interest in a variety of individual elements at values of [Fe/H] between -7 and -3, including alpha-elements, elements originating mostly in intermediate-mass stars, lithium, titanium, and r-process elements. These trends constrain not only models of the first stars and their supernovae, but provide a window into the physical conditions in early galaxies and when metal-free star formation may have ceased in the early universe.

This work was supported by the University of San Francisco Faculty Development Fund, and NSF grant AST-1637339. We thank the Aspen Center for Physics, where some of this work was conducted, and which is supported by National Science Foundation grant PHY-1607611.

115 – Astronomy Education and the Public: Research & Resources

115.01 – NASA’s Universe of Learning: Providing a Direct Connection to NASA Science for Learners of all Ages with ViewSpace

NASA’s Universe of Learning creates and delivers science-driven, audience-driven resources and experiences designed to engage and immerse learners of all ages and backgrounds in exploring the universe for themselves. The project is the result of a unique partnership between the Space Telescope Science Institute, Caltech/IPAC, Jet Propulsion Laboratory, Smithsonian Astrophysical Observatory, and Sonoma State University, and is one of 27 competitively-selected cooperative agreements within the NASA Science Mission Directorate STEM Activation program. The NASA’s Universe of Learning team draws upon cutting-edge science and works closely with Subject Matter Experts (scientists and engineers) from across the NASA Astrophysics Physics of the Cosmos, Cosmic Origins, and Exoplanet Exploration themes. As one example, NASA’s Universe of Learning program is uniquely able to provide informal learning venues with a direct connection to the science of NASA astrophysics via the ViewSpace platform.

ViewSpace is a modular multimedia exhibit where people explore the latest discoveries in our quest to understand the universe. Hours of awe-inspiring video content connect users’ lives with an understanding of our planet and the wonders of the universe. This experience is rooted in informal learning, astronomy, and earth science. Scientists and educators are intimately involved in the production of ViewSpace material. ViewSpace engages visitors of varying backgrounds and experience at museums, science centers, planetariums, and libraries across the United States. In addition to creating content, the Universe of Learning team is updating the ViewSpace platform to provide for additional functionality, including the introduction of digital interactives to make ViewSpace a multi-modal learning experience. During this presentation we will share the ViewSpace platform, explain how Subject Matter Experts are critical in creating content for ViewSpace, and how we are addressing audience needs and using evaluation to support a dedicated user base across the country.

114.05 – CEMP Stars in the Halo and Their Origin in Ultra-Faint Dwarf Galaxies

The very metal-poor (VMP; [Fe/H] < -2.0) and extremely metal-poor (EMP; [Fe/H] < -3.0) stars provide a direct view of Galactic chemical and dynamical evolution; detailed spectroscopic studies of these objects are the best way to identify and distinguish between various scenarios for the enrichment of early star-forming gas clouds soon after the Big Bang. It has been recognized that a large fraction of VMP (15-20%) and EMP stars (30-40%) possess significant over-abundances of carbon relative to iron, [C/Fe] > +0.7. This fraction rises to at least 80% for stars with [Fe/H] < -4.0. Recent studies show that the majority of CEMP stars with [Fe/H] < -3.0 belong to the CEMP-no sub-class, characterized by the lack of strong enhancements in the neutron-capture elements (e.g., [Ba/Fe] < 0.0). The CEMP-no abundance signature is commonly observed among stars ultra-faint dwarf spheroidal galaxies such as SEGUE-1. In addition, kinematic studies of CEMP-no stars strongly suggest an association with the outer-halo population of the Galaxy, which was likely formed from the accretion of low-mass mini-halos. These observations, and other lines of evidence, indicate that the CEMP-no stars of the Milky Way were born in low-mass dwarf galaxies, and later subsumed into the halo.

115.02 – NASA’s Universe of Learning: Engaging Subject Matter Experts to Support Museum Alliance Science Briefings

NASA’s Universe of Learning creates and delivers science-driven, audience-driven resources and experiences designed to engage and immerse learners of all ages and backgrounds in exploring the universe for themselves. The project is a unique partnership between the Space Telescope Science Institute, Caltech/IPAC, Jet Propulsion Laboratory, Smithsonian Astrophysical Observatory, and Sonoma State University and is part of the NASA SMD Science Activation Collective. The NASA’s Universe of Learning projects pull on the expertise of subject matter experts (scientist and engineers) from across the broad range of NASA Astrophysics themes and missions. One such project, which draws strongly on the expertise of the community, is the NASA’s Universe of Learning Science Briefings, which is done in collaboration with the NASA Museum Alliance. This collaboration presents a monthly hour-long discussion on relevant NASA astrophysics topics or events to an audience composed largely of informal educators from informal learning environments. These professional learning opportunities use experts and resources within the astronomical community to support increased interest and engagement of the informal learning community in NASA Astrophysics-related concepts and events. Briefings are designed to create a foundation for this audience using (1) broad science themes, (2) special events, or (3) breaking science news. The NASA’s Universe of Learning team engages subject matter experts to be speakers and present their science at these briefings to provide a direct connection to NASA Astrophysics science and provide the audience an opportunity to interact directly with scientists and engineers involved in NASA missions. To maximize
the usefulness of the Museum Alliance Science Briefings, each briefing highlights resources related to the science theme to support informal educators in incorporating science content into their venues and/or interactions with the public. During this presentation, learn how you can help contribute to the NASA's Universe of Learning and take part in Science Briefings.

Author(s): Emma Marcucci, Carolyn Slivinski, Brandon L. Lawton, Denise A. Smith, Gordon K. Squires, Anya A Biferno, Kathleen Lestitton, Lynn R. Cominsky, Janice C. Lee, Thalia Riveras, Allyson Walker, Marilyn Spisak


115.04 – Communicating the Science of Global Warming — the Role of Astronomers

Global Warming is one of the most important and urgent issues of our times, yet it is widely misunderstood among the general public (and politicians!). The American Astronomical Society has already joined many other scientific organizations in advocating for action on global warming (by supporting the AGU statement on global warming), but we as astronomers can do much more. The high public profile of astronomy gives us a unique platform — and credibility as scientists — for doing our part to educate the public about the underlying science of global warming. And while astronomers are not climate scientists, we use the same basic physics, and many aspects of global warming science come directly from astronomy, including the ways in which we measure the heat-absorbing potential of carbon dioxide and the hard evidence of greenhouse warming provided by studies of Venus. In this session, I will briefly introduce a few methods for communicating about global warming that I believe you will find effective in your own education efforts.

Author(s): Jeffrey Bennett
Institution(s): 1. Big Kid Science

115.03 – The Totality App — General Lessons and Future Eclipses

With the excitement around the 2017 eclipse, I worked with an app development company to create the Totality app, which featured eclipse predictions from the code of Xavier Jubier. We have since updated the app for future eclipses, including a Spanish version given the upcoming eclipses in Chile/Argentina. I will briefly discuss the current app, the process through which we developed it, and relevant lessons learned along the way that may be useful to others interested in developing apps for astronomy education.

Author(s): Jeffrey Bennett
Institution(s): 1. Big Kid Science

116 – Plenary Talk: The Relationship Between Galaxies and the Large-Scale Structure of the Universe, Alison Coil (University of California, San Diego)

116.01 – The Relationship Between Galaxies and the Large-Scale Structure of the Universe

I will describe our current understanding of the relationship between galaxies and the large-scale structure of the Universe, often called the galaxy-halo connection. Galaxies are thought to form and evolve in the centers of dark matter halos, which grow along with the galaxies they host. Large galaxy redshift surveys have revealed clear observational signatures of connections between galaxy properties and their clustering properties on large scales. For example, older, quiescent galaxies are known to cluster more strongly than younger, star-forming galaxies, which are more likely to be found in galactic voids and filaments rather than the centers of galaxy clusters. I will show how cosmological numerical simulations have aided our understanding of this galaxy-halo connection and what is known from a statistical point of view about how galaxies populate dark matter halos. This knowledge both helps us learn about galaxy evolution and is fundamental to our ability to use galaxy surveys to reveal cosmological information. I will talk briefly about some of the current open questions in the field, including galactic conformity and assembly bias.

Author(s): Alison L. Coil
Institution(s): 1. Univ. Of California San Diego

117 – Astronomy in Denver Poster Session

117.01 – Astronomy in Denver: Centenary of the 1918 Total Solar Eclipse Across Denver

Totality during the 2017 August 21 solar eclipse (Saros 145) traveled along a path across the United States similar to that which occurred for the eclipse on 1918 June 8 (Saros 126), but with a less west-northerly track. This placed Denver and its then new Chamberlin Observatory in the path of totality. Denver University astronomy Professor Herbert Howe offered use of the Chamberlin Observatory 20-inch f/15 refractor, with its Clark doublet lens and Sægmueller mounting, in service of eclipse-related research. In preparation for the eclipse, Professor Howe and assistants had spent the last three months of 1917, refurbishing mechanical aspects of the telescope. Edwin Frost, then Director of Yerkes Observatory, expressed interest and made a reconnaissance visit to the area in September 1917, reporting results in the Feb. 1918 issue of Popular Astronomy (http://adsabs.harvard.edu/abs/1918PA.....9....26R.103F). Frank Schlesinger, then director of Allegheny Observatory, asked if he might attach a special camera for star photography to the telescope at the eclipse, to test displacement of stars, in order to test a prediction of relativity theory. Among the additional visiting astronomical luminaries present on that June day in 1918 were Annie J. Cannon (Harvard), John Duncan (Wellesley), Herbert R. Morgan (U.S. Naval Observatory) and Robert Trumpler (Berkeley). To learn the results of all this eclipse preparedness, you will need to attend my talk in order to get “the rest of the story” or visit our twitter feed at: https://twitter.com/Chamberlin_Obs.

Author(s): Robert E. Stencel
Institution(s): 1. Univ. of Denver

117.02 – Astronomy in Denver: Polarization of Bow Shock Nebulae Around Massive Stars

Stellar wind bow shocks are structures created when stellar winds with supersonic relative velocities interact with the local interstellar medium (ISM). They can be studied to understand the properties of stars as well as the ISM. Since bow shocks are asymmetric, light becomes polarized by scattering in the regions of enhanced density they create. We use a Monte Carlo radiative transfer code called SLIP to simulate the polarization signatures produced by both resolved and unresolved bow shocks with analytically derived shapes and density structures. When electron scattering is the polarizing mechanism, we find that optical depth plays an important role in the polarization signatures. While results for low optical depths reproduce theoretical predictions, higher optical depths produce higher polarization and position angle rotations at specific viewing angles. This is due to the geometrical properties of the bow shock along with multiple scattering effects. For dust scattering, we find that the polarization signature is strongly affected by wavelength, dust size, dust composition, and viewing angle. Depending on the viewing angle, the polarization magnitude may increase or decrease as a function of wavelength. We will present results from these simulations and preliminary comparisons with observational data.

Author(s): Jeffrey Bennett
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Contributing team(s): Richard Ignace

117.03 – Astronomy in Denver: The polarization evolution of the luminous Type Ib SN 2012au
We present an analysis of the spectropolarimetric behavior of the Type Ib SN 2012au over the first 315 days of its evolution. Our data were obtained by the Supernova Spectropolarimetry Project using the CCD Imaging/Spectropolarimeter (SPOL) at the 61" Kuiper, the 90" Bok, and the 6.5-m MMT telescopes. SN 2012au was a very energetic, luminous, and slowly evolving event that may represent an intermediate case between normal core-collapse supernovae and the enigmatic superluminous supernovae. Strong, time-variable line polarization signatures, particularly in the He II λ5876 line, support previous hypotheses of an asymmetric explosion and allow us to trace detailed structures within the supernova ejecta as they change over time. We compare the polarimetric evolution of the continuum and emission lines in SN 2012au and compare its behavior with that of other bright and polarimetrically variable supernovae.

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Contributing team(s): The Supernova Spectropolarimetry Project (SNSPOL)

117.04 – Astronomy in Denver: Effects of a summer camp on girls’ preconceived notions of careers in STEM
Despite gains in recent years, gender disparities persist in fields related to science, technology, engineering, and mathematics (STEM). Although young women can perform as well as their male peers in STEM courses and tests, they are less likely to pursue higher education and careers in STEM. Our study examined the effectiveness of a STEM-focused summer camp at increasing middle-school girls’ career aspirations in STEM and self-confidence with respect to scientific topics. The 15 participants were Denver-area girls ages 10 to 13 years old from groups underrepresented in STEM fields. During the weeklong DU SciTech camp, these girls built telescopes and computers, collected and classified insects, completed inquiry activities, and interacted with female STEM professionals from a variety of scientific fields and racial backgrounds. We hypothesized that camp attendance would expand girls’ perceptions of who does science, increase their awareness of and interest in STEM careers, and increase their scientific self-efficacy, or belief in their ability to succeed at STEM tasks. We found that DU SciTech improved the girls’ scientific self-efficacy and awareness of STEM careers, but it did not increase their (already high) interest in pursuing their own careers in STEM. We will present our results and discuss their implications for future summer camps and efforts to broaden STEM participation by young women from underrepresented groups.

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117.05 – Astronomy In Denver: Polarization of Stellar Wind Bow Shocks
When a star with stellar wind moves through the interstellar medium (ISM) at a relative supersonic velocity, an arch like structure known as a stellar wind bow shock is formed. Studying the characteristics of these structures can further our understanding of evolved stellar winds and the composition of the ISM. Observations of these structures have been performed for some time, but the recent discovery of many bow shock structures have opened more ways to study them. These stellar wind bow shocks display aspherical shapes, which cause light scattering through the dense shock material to become polarized. We selected a target star for observation using a catalog compiled from previous studies and observed it in polarized light with the University of Denver’s DUSTPol instrument. Our group has also simulated the polarization of stellar wind bow shocks using a Monte Carlo radiative transfer code. We present the data from our observations and compare them with the simulations. We also discuss the contribution of interstellar polarization to the data.

Author(s): Austin A Lin1, Manisha Shrestha1, Tristan Wolfe1, Robert E. Stencel1, Jennifer L. Hoffman1
Institution(s): 1. University of Denver

118 – Astronomy Education: Mentoring and Research Across the Professional Continuum & Some Curriculum Poster Session

118.01 – Peer Mentoring through eAlliances
Being a woman in astronomy or physics can be a very isolating experience. Peer mentoring has been shown to help combat this isolation. eAlliance, an NSF ADVANCE PLAN-D program hosted by AAPT, is seeking to establish mutual mentoring networks of like-minded students. In this poster, we report on our work in building eAlliances and supporting the mentor and mentee, interacting in a virtual environment.

Author(s): Cindy Blaha2, Beth Cunningham1, Anne Cox4, Idalia Ramos5, Barbara Whitten3

118.02 – The Cal-Bridge Program: Supporting Diverse Graduate Students in Astrophysics
The mission of the Cal-Bridge program is to increase the number of underrepresented minority and women students completing a bachelor’s degree and entering a PhD program in astronomy, physics, or closely-related fields. To do so, we have built a network of faculty at diverse higher education institutions, including University of California (UC) campuses, California State Universities (CSUs), and community colleges dedicated to this goal. Students selected for our program are known as Cal-Bridge Scholars, and we give them a wide variety of support: (1) financial scholarships in their junior/senior years at CSU and their first year of graduate school at a UC, (2) intensive mentoring by a pair of CSU and UC faculty members, (3) tutoring, (4) professional development workshops, (5) exposure to research opportunities at various universities, and (6) membership in a growing cohort of like-minded students. In this poster, we report on our work in designing an effective mentoring program and developing tools like our mentoring and graduate application handbooks, and we
discuss our tutoring program and the professional development workshops we have designed, and we report on their effectiveness. Funding for this program is provided by NSF-SSTEM Grant #1356133.

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### 118.03 – Cal-Bridge and CAMPARE: Engaging Underrepresented Students in Physics and Astronomy

We describe two programs, Cal-Bridge and CAMPARE, with the common mission of increasing participation of groups traditionally underrepresented in astronomy, through summer research opportunities, in the case of CAMPARE, scholarships in the case of Cal-Bridge, and significant mentoring in both programs, creating a national impact on their numbers successfully pursuing a PhD in the field.

In 9 years, the CAMPARE program has sent 150 students, >80% from underrepresented groups, to conduct summer research at one of 14 major research institutions throughout the country. Of the CAMPARE scholars who have graduated with a Bachelor’s degree, almost two-thirds (65%) have completed or are pursuing graduate education in physics, astronomy, or a related field, at institutions including UCLA, UC Riverside, UC Irvine, UC Santa Barbara, USC, Stanford, Univ. of Arizona, Univ. of Washington, Univ. of Rochester, Michigan State Univ., Georgia Tech, Georgia State Univ., Kent State, Indiana Univ., Univ. of Oregon, Syracuse Univ., Montana State Univ., and the Fisk- Vanderbilt Master’s-to-PhD program.

Now in its fourth year, the Cal-Bridge program is a CSU-UC Bridge program comprised of physics and astronomy faculty from 9 University of California (UC), 15 California State University (CSU), and more than 30 California Community College (CCC) campuses throughout California. In the first four years, 34 Cal-Bridge Scholars have been selected, including 22 Hispanic, 3 African-American and 13 women students, 10 of whom are from URM groups. Thirty (30) of the 34 Cal-Bridge Scholars are first generation college students. In the last three years, 17 of 21 Cal-Bridge Scholars have begun or been accepted PhD programs in physics or astronomy at top PhD programs nationally. Three (3) of these scholars have won NSF Graduate Research Fellowships; one more received an Honorable Mention.

Once selected, Cal-Bridge Scholars benefit from substantial financial support, intensive, joint mentoring by CSU and UC faculty, professional development workshops, and exposure to research opportunities at the participating UC campuses. Funding for this program is provided by NSF-DUE SSTEM Grant #1356133.

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### 118.04 – Impacts of a Course-based Undergraduate Research Experience in Introductory Astronomy Using Robotic Telescopes

As part of a general education undergraduate astronomy course at a minority-serving university in the Midwestern US, students completed an observing project with the Global Telescope Network (GTN), where they participated in realistic practices used by professional astronomers, including proposal writing and peer review. First, students went through the process of applying for telescope time by choosing an astronomical object and writing an observing proposal. Then they performed an NSF-style review of classmates’ proposals, including written peer reviews and a review panel. After obtaining images from GTN telescopes, students presented their project and findings in front of the class.

This study investigates students’ experiences and perceived impacts of participation in the project. The data analyzed includes an essay assignment [N = 59] administered over seven semesters and individual interviews [N = 8] collected over two semesters. Students were prompted to address what they liked, disliked, or would change about the project experience. These data were coded iteratively into nine categories. A Kruskal-Wallis (KW) test was used to determine that essay results from different semesters could be combined. We find that students expressed an overall strong positive affect, increased perception of self-efficacy, enjoyment of the experience of peer review, an appreciation for being able to use real scientific tools and to take on the role of astronomers, as well as a small number of dislikes such as real-world constraints on observing.

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### 118.05 – Watching Stars Grow: The adaptation and creation of instructional material for the acquisition, reduction, and analysis of data using photometry tools at the WestRock Observatory.

The WestRock observatory at Columbus State University provides laboratory and research opportunities to earth and space science students specializing in astrophysics and planetary geology. Through continuing improvements, the observatory has been expanding the types of research carried out by undergraduates. Photometric measurements are an essential tool for observational research, especially for objects of variable brightness. Using the American Association of Variable Star Observers (AAVSO) database, students choose variable star targets for observation. Students then perform observations to develop the ability to properly record, calibrate, and interpret the data. Results are then submitted to a large database of observations through the AAVSO.

Standardized observation procedures will be developed in the form of manuals and instructional videos specific to the equipment housed in the WestRock Observatory. This procedure will be used by students conducting laboratory exercises and undergraduate research projects that utilize photometry. Such hands-on, direct observational experience will help to familiarize the students with observational techniques and contribute to an active dataset, which in turn will prepare them for future research in their field.

In addition, this set of procedures and the data resulting from them will be used in the wider outreach programs of the WestRock Observatory, so that students and interested public nationwide can learn about both the process and importance of photometry in astronomical research.

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### 118.06 – NGC 4622:: A clear example of spiral density wave star formation unused in textbooks.

Refer to the poster HST images or to http://heritage.stsci.edu/2002/03/index.html. The top northeastern (NE) arm of NGC 4622 winds outward clockwise (CW) showing a beautiful “beads on a string” blue stellar associations on the CONCAVE SIDE of the arm. These are nicely offset CW in position from the density concentration of old yellow stars in the arms. The displacement would result from aggregation of gas clouds as they orbit CW into a more slowly turning stellar disk arm pattern. There is a time delay until the associations form and light up on the concave side. Farther inward along the top NE arm, the lit-up associations occur in the MIDDLE of the stellar arm. This is characteristic of the co-
119.01 – Sixteen Years of the Hubble Space Telescope's Advanced Camera for Surveys: Calibration Update

The Advanced Camera for Surveys (ACS) has been a workhorse HST imager for over sixteen years, subsequent to its Servicing Mission 3B installation in 2002. The once defunct ACS Wide Field Channel (WFC) has now been operating nearly twice as long (>9yrs) since its Servicing Mission 4 (SM4) repair than it had originally operated prior to its 2007 failure. Despite the accumulating radiation damage to the WFC CCDs during their long stay in low Earth orbit, ACS continues to be heavily exploited by the HST community as both a prime and a parallel detector.

During past year, there have been two new releases of the CALACS image reduction pipeline that have incorporated several recent advancements in ACS calibration capabilities. We review these updates, along with the enhanced calibration reference files (superbiases, superdarks, etc.) associated with these CALACS releases. We also present results from long-term monitoring of WFC dark current and readout noise, and from new studies of detector performance from both WFC and the ACS Solar Blind Channel (SBC). Highlights include: 1) improved characterization of WFC post-flash LED illumination, including a low-level annual modulation of LED intensity; 2) comprehensive assessment of SBC dark current as a function of detector operating temperature, and of SBC operating temperature versus duration of use; and 3) an update to the WFC bad-pixel table resulting from a minor particulate-contamination event in May 2017.

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Institution(s): 1. Space Telescope Science Institute
Contributing team(s): ACS Instrument Team

119.02 – Accounting for Dark Current Accumulated during Readout of Hubble's ACS/WFC Detectors

We investigate the properties of excess dark current accumulated during the 100-second full-frame readout of the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC) detectors. This excess dark current, called “readout dark”, gives rise to ambient background gradients and hot columns in each ACS/WFC image. While readout dark signal is removed from science images during the bias correction step in CALACS, the additional noise from the readout dark is currently not taken into account. We develop a method to estimate the readout dark noise properties in ACS/WFC observations. We update the error (ERR) extensions of superbias images to include the appropriate noise from the ambient readout dark gradient and stable hot columns. In recent data, this amounts to about 5 e-/pixel added variance in the rows farthest from the WFC serial registers, and about 7 to 30 e-/pixel added variance along the stable hot columns. We also flag unstable hot columns in the superbias data quality (DQ) extensions. The new reference file pipeline for ACS/WFC implements these updates to our superbias creation process.

Author(s): Jenna E. Ryon, Norman A. Grogin, Dan A. Coe
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Contributing team(s): ACS Team

119.03 – Replacing the IRAF/PyRAF Code-base at STScI: The Advanced Camera for Surveys (ACS) IRAF/PyRAF are no longer viable on the latest hardware often used by HST observers, therefore STScI no longer actively supports IRAF or PyRAF for most purposes. STScI instrument teams are in the process of converting all of our data processing and analysis code from IRAF/PyRAF to Python, including our calibration reference file pipelines and data reduction software. This is exemplified by our latest ACS Data Handbook, version 9.0, which was recently published in February 2018. Examples of IRAF and PyRAF commands have now been replaced by code blocks in Python, with references linked to documentation on how to download and install the latest Python software via Conda and AstroConda. With the temporary exception of the ACS slitless spectroscopy tool aXe, all ACS-related software is now independent of IRAF/PyRAF. A concerted effort has been made across STScI divisions to help the astronomical community transition from IRAF/PyRAF to Python, with tools such as Python Jupyter notebooks being made to give users workable examples. In addition to our code changes, the new ACS data handbook discusses the latest developments in charge transfer efficiency (CTE) correction, bias de-striping, and updates to the creation and format of calibration reference files among other topics.

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Institution(s): 1. STScI
Contributing team(s): STScI ACS (Advanced Camera for Surveys) Team

119.04 – Re-visiting the Amplifier Gains of the HST/ACS Wide Field Channel CCDs

For the first time since HST Servicing Mission 4 (SM4) in May 2009, we present an analysis of the amplifier gains of the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC) CCDS. Using a series of in-flight flat-field exposures taken in November 2017 with a tungsten calibration lamp, we utilize the photon transfer method to estimate the gains of the WFC1 and WFC2 CCD amplifiers. We find evidence that the gains of the four readout amplifiers have changed by a small, but statistically significant, 1–2% since SM4. We further present a study of historical ACS/WFC observations of the globular cluster NGC 104 (47 Tuc) in an attempt to estimate the time dependence of the gains.

Author(s): Tyler D. Desjardins, Norman A. Grogin
Institution(s): 1. Space Telescope Science Institute
Contributing team(s): The ACS Team

119.05 – Updating the HST/ACS G800L Grism Calibration

We present results from our ongoing work on obtaining newly derived trace and wavelength calibrations of the HST/ACS G800L grism and comparing them to previous set of calibrations. Past calibration efforts were based on 2003 observations. New observations of an emission line Wolf-Rayet star (WR96) were recently taken in HST Cycle 25 (PID: 15401). These observations would make NGC 4622 even better for use in introductory astronomy texts. Students can debate the origin of this galaxy's strange arm pattern which, ironically, matches density wave predictions so well. This is better than simply reading a textbook and thinking that all is explained. See G. G. Byrd; T. Freeman; S. Howard; R. J. Buta (2008). Astron. J., 135, p. 408–413 and references there for observations and hypotheses about NGC 4622's arms. This work was supported by NSF grant AST 02-0177 to Blevin State College, Fayette, AL. Also see https://www.researchgate.net/profile/Gene_Byrd2

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Institution(s): 1. University of Alabama - Tuscaloosa
are used to analyze and measure various grism properties, including wavelength calibration, spectral trace/tilt, length/size of grism orders, and spacing between various grism orders. To account for the field dependence, we observe WR96 at 3 different observing positions over the HST/ACS field of view. The three locations are the center of chip 1, the center of chip 2, and the center of the WFC1A-2K subarray (center of WFC Amp A on chip 1). This new data will help us to evaluate any differences in the G800L grism properties compared to previous calibration data, and to apply improved data analysis techniques to update these old measurements.

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**Contributing team(s):** ACS Team

**119.06 – A Parameter Study on the Effect of Impactor Size for NASA’s DART Mission**

We have modeled the impact of the Double Asteroid Redirection Test (DART) spacecraft into the binary near-Earth asteroid (65803) Didymos. While the primary object is approximately 800 meters across, its secondary body (“moonlet” Didymoon) has a diameter of 150 meters, which is thought to be a much more typical size for the kind of asteroid that would pose a hazard to Earth. DART will be the first demonstration of the kinetic impact technique to change the motion of an asteroid in space, an important consideration for understanding our capabilities in planetary defense of Near-Earth Asteroids. Recent modeling of this impact has used full-density solid aluminum spheres with a mass of approximately 500 kg. Many of the published scaling laws for crater size and diameter as well as ejecta modeling assume this type of impactor, although the actual spacecraft shape being considered for the DART Mission impact is not solid and does not contain a solid dedicated kinetic impactor – rather, the spacecraft itself is considered the impactor. Since the 500 kg hollow spacecraft is significantly larger (~100 x 100 x 200 cm) in size than a solid aluminum sphere (radius ~ 36 cm) the resulting impact dynamics are quite different. Here we have modeled both types of impacts and compare the results of the simulations for crater size, depth, and ejecta for a solid sphere (R = 36 cm) and cylindrical spacecraft (R = 20, 50, and 100 cm), while maintaining a constant mass and material density. This work will allow for a more robust comparison of the momentum enhancement β-factor, which describes the gain in a momentum transfer exerted by the impacting spacecraft on a Near-Earth Object due to ejecta momentum escape. (LA-UR-18-21571)

**Author(s):** Amanda Truitt¹, Robert Weaver¹, Galen Gisler¹

**Institution(s):** 1. Los Alamos National Laboratory

**119.07 – The Dual-channel Extreme Ultraviolet Continuum Experiment: Sounding Rocket EUV Observations of Local B Stars to Determine Their Potential for Supplying Intergalactic Ionizing Radiation**

We describe the scientific motivation and technical development of the Dual-channel Extreme Ultraviolet Continuum Experiment (DEUCE). DEUCE is a sounding rocket payload designed to obtain the first flux-calibrated spectra of two nearby B stars in the EUV 650-150Å bandpass. This measurement will help in understanding the ionizing flux output of hot B stars, calibrating stellar models and commenting on the potential contribution of such stars to reionization. DEUCE consists of a grazing incidence Wolter II telescope, a normal incidence holographic grating, and the largest (8’ x 8’) microchannel plate detector ever flown in space, covering the 650-150Å band in medium and low resolution channels. DEUCE will launch on December 1, 2018 as NASA/CU sounding rocket mission 36.331 UG, observing Epsilon Canis Majoris, a B2 II star.

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**Institution(s):** 1. University of Colorado at Boulder

**119.08 – Performance of the STIS CCD Dark Rate Temperature Correction**

Since July 2001, the Space Telescope Imaging Spectrograph (STIS) onboard Hubble has operated on its Side-2 electronics due to a failure in the primary Side-1 electronics. While nearly identical, Side-2 lacks a functioning temperature sensor for the CCD, introducing a variability in the CCD operating temperature. Previous analysis utilized the CCD housing temperature telemetry to characterize the relationship between the housing temperature and the dark rate. It was found that a first-order 7%°C uniform dark correction demonstrated a considerable improvement in the quality of dark subtraction on Side-2 era CCD data, and that value has been used on all Side-2 CCD darks since. In this report, we show how this temperature correction has performed historically. We compare the current 7%°C value against the ideal first-order correction at a given time (which can vary between ~6%/°C and ~10%/°C) as well as against a more complex second-order correction that applies a unique slope to each pixel as a function of dark rate and time. At worst, the current correction has performed ~1% worse than the second-order correction. Additionally, we present initial evidence suggesting that the variability in pixel temperature-sensitivity is significant enough to warrant a temperature correction that considers pixels individually rather than correcting them uniformly.

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**Contributing team(s):** STScI STIS Team

**119.09 – Improvements to the Hubble Space Telescope COS/FUV Wavelength Calibration at Lifetime Position 4**

The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope in 2009, and the FUV detector is currently operating at the 4th lifetime position (LP4). The COS team at the Space Telescope Science Institute has been improving the wavelength calibration of the FUV channel at each lifetime position. For the LP4 solution we obtained special calibration data as well as new lamp spectra to update the lamp template used at LP4 with the goal of achieving a wavelength calibration accuracy of ± 3 pixels. Additionally, we derived a new solution for the G130M/1222 cenwave which we expect to be more frequently used at this lifetime position due to the COS2025 policy in place on the other G130M settings. Here we present the results and methodology behind the wavelength calibration solutions at LP4.

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**Institution(s):** 1. Space Telescope Science Institute

**119.10 – New HST/COS FUV Modes G140L/800 and G160M/1533**

We present two new observing modes that are being offered for the far-ultraviolet (FUV) channel on the Cosmic Origins Spectrograph (COS), and an initial overview of the science investigations they enable. The FUV channel on COS currently operates in the 900-2150 Å wavelength region. It consists of two medium resolution gratings G130M and G160M, and a low resolution grating G140L. The detector consists of two segments (FUVB, shortward and FUVB, longward wavelengths) with 2 cm between them. Each grating has a number of central wavelength settings (cenwaves) available. The settings place different portions of the spectrum on the detector segments, and the focus at each cenwave is set to optimize spectral resolution in the middle of its wavelength range.

The first new mode is G140L/800, which places 800-1950 Å on FUVA. The grating rotation and focus for this mode are set to minimize the height of the spectrum on the detector, and thereby the background, in the region below 1100 Å. This results in an increased sensitivity at these wavelengths compared to the 1280 cenwave. The second mode, G160M/1533, extends the short-wavelength coverage of the grating by 44 Å to overlap with the longest wavelengths covered by the G120M/1222 setting. This
allows a broad wavelength range to be covered using just two medium resolution settings without placing the key gain-sag contributor, Ly-alpha, on the detector.

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119.11 – Improved Astronomical Instrumentation for the Far Ultra-Violet
Recent technological advances have opened up new instrument capabilities in the ultraviolet. Of particular interest are advanced deposition techniques that have made lithium fluoride (LiF) based mirrors more accessible, achieving greater than 80% broadband reflectivity down into the Lyman UV (100 nm). Traditional MgF2 protected aluminum mirrors cut off at 115 nm, missing crucial tracers of warm gas and molecules. The hypersonic sensitivity of LiF, which adds mission risk and cost, has also been mitigated with a thin capping layer of a more durable substance, making LiF mirrors accessible without onerous environmental procedures. These advances open up a new paradigm in UV astronomy by enabling multi-reflection systems in the Lyman UV. We present recent progress in the testing of eLiF-based optics, and then discuss the potential scientific avenues this opens up in UV astronomy.

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119.12 – WebbPSF: Updated PSF Models Based on JWST Ground Testing Results
WebbPSF is a widely-used package that allows astronomers to create simulated point spread functions (PSFs) for the James Webb Space Telescope (JWST). WebbPSF provides the user with the flexibility to produce PSFs for direct imaging and coronographic modes, for a range of filters and masks, and across all the JWST instruments. These PSFs can then be analyzed with built-in evaluation tools or can be output to be used with users' own tools. In the most recent round of updates, the accuracy of the PSFs have been improved with updated analyses of the instrument test data from NASA Goddard and with the new data from the testing of the combined Optical Telescope Element and Integrated Science Instrument Module (OTIS) at NASA Johnson. A post-processing function applying detector effects and pupil distortions to input PSFs has also been added to the WebbPSF package.

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It is well-known that HST images, taken with ACS/WFC and WFC3/UVIS, have substantial geometric distortion. Over the years our knowledge about this distortion has been vastly improved. Nevertheless, in certain applications it may not be good enough. Preliminary results of comparison state-of-the-art HST astrometric standards and the Gaia DR1 indicate significant scale difference, global rotation, and edge effects in the HST data. However, in terms of positional precision the HST standards are not surpassed yet. The next release of Gaia data DR2 were used to finalize and improve the HST astrometric calibrations down to 0.5 mas or better.

Author(s): Vera Kozhurina-Platais1, Norman A. Groggin1, Elena Sabb1
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The Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) Ultraviolet-Visible (UVIS) detector has acquired roughly 12,000 dark images since the installation of WFC3 in 2009, as part of a daily monitoring program to measure the intrinsic dark current of the detector. These images have been reconfigured into 'pixel history' images in which detector columns are extracted from each dark and placed into a new time-ordered array, allowing for efficient analysis of a given pixel's behavior over time. We discuss how we measure each pixel's stability, as well as plans for a new Data Quality (DQ) flag to be introduced in a future release of the WFC3 calibration pipeline (CALWF3) for flagging pixels that are deemed unstable.

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Contributing team(s): The Wide Field Camera 3 Team

119.15 – Deriving the polarization behavior of many-layer mirror coatings
End-to-end models of astronomical instrument performance are becoming commonplace to demonstrate feasibility and guarantee performance at large observatories. Astronomical techniques like adaptive optics and high contrast imaging have made great strides towards making detailed performance predictions, however, for polarimetric techniques, fundamental tools for predicting performance do not exist. One big missing piece is predicting the wavelength and field of view dependence of a many-mirror articulated optical system particularly with complex protected metal coatings. Predicting polarization performance of instruments requires combining metrology of mirror coatings, tools to create mirror coating models, and optical modeling software for polarized beam propagation. The inability to predict instrument induced polarization or to define polarization performance expectations has far reaching implications for up and coming major observatories, such as the Daniel K. Inouye Solar Telescope (DKIST), that aim to take polarization measurements at unprecedented sensitivity and resolution. Here we present a method for modelling the wavelength dependent refractive index of an optic using Berreman calculus - a mathematical formalism that describes how an electromagnetic field propagates through a birefringent medium. From Berreman calculus, we can better predict the Mueller matrix, diattenuation, and retardance of an arbitrary thicknesses of amorphous many-layer coatings as well as stacks of birefringent crystals from laboratory measurements. This will allow for the wavelength dependent refractive index to be accurately determined and the polarization behavior to be derived for a given optic.

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120 – Extrasolar Planets Poster Session

120.01 – TESS Follow-up Observing Programs at the University of Wyoming
The Transiting Exoplanet Survey Satellite (TESS), launched in Spring 2018, will detect thousands of new exoplanet candidates. These candidates will need to be vetted by ground-based observatories to rule out false positives. The Observatories at the University of Wyoming are well-positioned to take active roles in TESS Follow-Up Observing Program (TFOP) Working Groups. The 0.6-m Red Buttes Observatory has already demonstrated its capability to do precision photometric monitoring of transiting exoplanet targets as a participant in the Kilodegree Extremely Little Telescope Follow-Up Network (KELT-FUN). A new echelle
spectrograph, Fiber High-Resolution Echelle (FHR-E), being built for the 2.3-m Wyoming InfraRed Observatory (WIRO), will enable precision radial velocity measurements of exoplanet candidates. Over 180 nights/year at both observatories will be available to our team to undertake follow-up observations of TESS Objects of Interest (TOIs). We anticipate making significant contributions to new exoplanet discoveries in the era of TESS.

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Institution(s): 1. University of Indiana, 2. University of Wyoming

120.02 – The Ground-Based Transmission Spectrum of HD 189733b as Generated Through Multiple Broadband Filter Observations

We present new multi-broadband transit photometry of HD 189733b observed with the Wyoming Infrared Observatory. With an ensemble of Sloan filter observations across multiple transits we have created an ultra-low resolution transmission spectrum to discern the nature of the exoplanet atmosphere. This data set exemplifies the capabilities of the 2.3 m observatory. The analysis was performed with a Markov-Chain Monte-Carlo method assisted by a Gaussian-processes regression model. These observations were taken as part of the University of Wyoming’s 2017 Research Experience for Undergraduates (REU) and represent one of multiple hot Jupiter exoplanet targets for which we have transit event observations in multiple broadband filters.


120.03 – Photometer Performance Assessment in TESS SPOC Pipeline

This poster describes the Photometer Performance Assessment (PPA) software component in the Transiting Exoplanet Survey Satellite (TESS) Science Processing Operations Center (SPOC) pipeline, which is developed based on the Kepler science pipeline. The PPA component performs two tasks: the first task is to assess the health and performance of the instrument based on the science data sets collected during each observation sector, identifying out of bounds conditions and generating alerts. The second is to combine the astrometric data collected for each CCD readout channel to construct a high fidelity record of the pointing history for each of the 4 cameras and an attitude solution for the TESS spacecraft for each 2-min data collection interval. PPA is implemented with multiple pipeline modules: PPA Metrics Determination (PM), PPA MDL Aggregator (PAG), and PPA Attitude Determination (PAD). The TESS Mission is funded by NASA’s Science Mission Directorate. The SPOC is managed and operated by NASA Ames Research Center.

Author(s): Jie Li3, Douglas A. Caldwell3, Jon Michael Jenkins4, Joseph D. Twicken3, Bill Wohler3, Xiaolan Chen4, Mark Rose3
Institution(s): 1. Leidos, 2. NASA Ames Research Center, 3. SETI Institute, 4. SGT Inc
Contributing team(s): TESS Science Processing Operations Center

120.04 – Characterization and Validation of Transiting Planets in the TESS SPOC Pipeline

Light curves for Transiting Exoplanet Survey Satellite (TESS) target stars will be extracted and searched for transiting planet signatures in the Science Processing Operations Center (SPOC) Science Pipeline at NASA Ames Research Center. Targets for which the transiting planet detection threshold is exceeded will be processed in the Data Validation (DV) component of the Pipeline. The primary functions of DV are to (1) characterize planets identified in the transiting planet search, (2) search for additional transiting planet signatures in light curves after modeled transit signatures have been removed, and (3) perform a comprehensive suite of diagnostic tests to aid in discrimination between true transiting planets and false positive detections. DV data products include extensive reports by target, one-page summaries by planet candidate, and tabulated transit model fit and diagnostic test results. DV products may be employed by humans and automated systems to vet planet candidates identified in the Pipeline. TESS will launch in 2018 and survey the full sky for transiting exoplanets over a period of two years. The SPOC pipeline was ported from the Kepler Science Operations Center (SOC) codebase and extended for TESS after the mission was selected for flight in the NASA Astrophysics Explorer program. We describe the Data Validation component of the SPOC Pipeline. The diagnostic tests exploit the flux (i.e., light curve) and pixel time series associated with each target to support the determination of the origin of each purported transiting planet signature. We also highlight the differences between the DV components for Kepler and TESS. Candidate planet detections and data products will be delivered to the Mikulski Archive for Space Telescopes (MAST); the MAST URL is archive.stsci.edu/tess. Funding for the TESS Mission has been provided by the NASA Science Mission Directorate.

Author(s): Joseph D. Twicken3, Douglas A. Caldwell3, Misty Davies2, Jon Michael Jenkins4, Jie Li3, Robert L. Morris3, Mark Rose1, Jeffrey C Smith3, Peter Tenenbaum3, Eric Ting2, Bill Wohler3
Institution(s): 1. Leidos, 2. NASA Ames Research Center, 3. SETI Institute

120.05 – The TESS Transiting Planet Search Predicted Recovery and Reliability Rates

The Transiting Exoplanet Survey Satellite (TESS) will search for transiting planet signatures via the Science Processing Operations Center (SPOC) Science Pipeline at NASA Ames Research Center. We report on predicted transit recovery and reliability rates for planetary signatures. These estimates are based on simulated runs of the pipeline using realistic stellar models and transiting planet populations along with best estimates for instrumental noise, thermal induced focus changes, instrumental drift and stochastic artifacts in the light curve data. Key sources of false positives are identified and summarized. TESS will launch in 2018 and survey the full sky for transiting exoplanets over a period of two years. The SPOC pipeline was ported from the Kepler Science Operations Center (SOC) codebase and extended for TESS after the mission was selected for flight in the NASA Astrophysics Explorer program. Candidate planet detections and data products will be delivered to the Mikulski Archive for Space Telescopes (MAST); the MAST URL is archive.stsci.edu/tess. Funding for the TESS Mission has been provided by the NASA Science Mission Directorate.

Author(s): Jeffrey C Smith3, Douglas A. Caldwell3, Misty Davies2, Jon Michael Jenkins4, Jie Li3, Robert L. Morris3, Mark Rose1, Peter Tenenbaum3, Eric Ting2, Joseph D. Twicken3, Bill Wohler3
Institution(s): 1. Leidos, 2. NASA Ames Research Center, 3. SETI Institute

120.06 – Status of the TESS Science Processing Operations Center

The Transiting Exoplanet Survey Satellite (TESS) was selected by NASA’s Explorer Program to conduct a search for Earth’s closest cousins starting in 2018. TESS will conduct an all-sky transit survey of F, G and K dwarf stars between 4 and 12 magnitudes and M dwarf stars within 200 light years. TESS is expected to discover 1,000 small planets less than twice the size of Earth, and to measure the masses of at least 50 of these small worlds. The TESS science pipeline is being developed by the Science
Processing Operations Center (SPOC) at NASA Ames Research Center based on the highly successful Kepler science pipeline. Like the Kepler pipeline, the TESS pipeline provides calibrated pixels, simple and systematic error-corrected aperture photometry, and centroid locations for all 200,000+ target stars observed over the 2-year mission, along with associated uncertainties. The pixel and light curve products are modeled on the Kepler archive products and will be archived to the Mikulski Archive for Space Telescopes (MAST). In addition to the nominal science data, the 30-minute Full Frame Images (FFIs) simultaneously collected by TESS will also be calibrated by the SPOC and archived at MAST. The TESS pipeline searches through all light curves for evidence of transits that occur when a planet crosses the disk of its host star. The Data Validation pipeline generates a suite of diagnostic metrics for each transit-like signature, and then extracts planetary parameters by fitting a limb-darkened transit model to each potential planetary signature. The results of the transit search are modeled on the Kepler transit search products (tabulated numerical results, time series products, and pdf reports) all of which will be archived to MAST. Synthetic sample data products are available at https://archive.stsci.edu/tess/ete-6.html.

Funding for the TESS Mission has been provided by the NASA Science Mission Directorate.

Author(s): Jon Michael Jenkins¹, Douglas A. Caldwell², Misty Davies¹, Jie Li², Robert L. Morris², Mark Rosè³, Jeffrey C Smith², Peter Tenenbaum², Eric Ting¹, Joseph D. Twicken², Bill Wohler²

Institution(s): 1. NASA Ames Research Center, 2. SETI Institute, 3. SGT, INC.

120.07 – Discovery of KELT-21b through photometric follow-up observations

KELT-21b is an exoplanet classified as a hot Jupiter transiting the star HD 332124. The host star has the highest projected rotation velocity of any known star to host a transiting hot Jupiter. This target was found by the KELT (Kilo-degree Extremely Little Telescope) program. KELT-FUN (Follow-Up Network) is tasked with doing follow up observations for KELT exoplanet candidates. KELT-21b was one of those targets that drew interest due to its size and orbit around a hot star. As a part of the KELT-FUN team photometric observations were taken by the Red Buttes Observatory at the University of Wyoming which contributed to the discovery of KELT-21b. Our experience gained by KELT-FUN will enable us to follow up on targets identified by TESS.

Author(s): Daniel A. Hancock¹, David Kasper³, Hannah Jang-Condell¹, Aman Kar¹, Rebecca Sorber¹, Afifah Suaimi¹

Institution(s): 1. University of Wyoming

120.08 – Worlds Beyond: Follow-up Observations and Confirmation of K2 Exoplanet Candidates

We present the results of an 8-month follow-up transit photometry campaign focused on exoplanet candidates produced by the K2 mission. Observations were conducted at the McConnell Roofop Observatory at Smith College in Northampton, MA, with a 16” telescope and CCD. Targets were observed through a 400-700 nm broadband filter at a 1 minute cadence. We attempted to observe the complete duration of the transit plus a minimum one-hour baseline before and after the transit event whenever possible. Our observations typically reach an RMS of 2 millimags for an 11th-magnitude star. Candidates were selected based on a number of factors, including a transit depth of around 10 millimags, a host star magnitude between 10-13, a duration that is observable over the span of a night, and a period shorter than 30 days. There are currently around 700 unconfirmed exoplanets from K2, and these criteria shortened that list to around 20 ideal candidates, many of which were flagged as possible false positives. Our results showcase the capability of small observatories to conduct precise follow-up observations of exoplanet transits.

Author(s): Rachel O'Connor¹, James Lowenthal¹, Olivia Cooper¹, Elana Helou¹, Emily Papineau¹, Annie Peck¹, Loren Stephens¹, Kerry Walker¹

Institution(s): 1. Smith College

120.09 – False Positives in Exoplanet Detection

Our team at the University of Wyoming uses a 0.6 m telescope at RBO (Red Buttes Observatory) to help confirm results on potential exoplanet candidates from low resolution, wide field surveys shared by the KELT (Kilo-degree Extremely Little Telescope) team. False positives are common in this work. We carry out transit photometry, and this method comes with special types of false positives. The most common false positive seen at the confirmation level is an EB (eclipsing binary). Low resolution images are great in detecting multiple sources for photometric dips in light curves, but they lack the precision to decipher single targets at an accurate level. For example, target star KC18C00621 needed RBO’s photometric precision to determine there was a nearby EB causing exoplanet type light curves. Identifying false positives with our telescope is important work because it helps eliminate the waste of time taken by more expensive telescopes trying to rule out negative candidate stars. It also furthers the identification of other types of photometric events, like eclipsing binaries, so they can be studied on their own.

Author(s): Jacob Lequaire¹, David Kasper³, Hannah Jang-Condell¹, Aman Kar¹, Rebecca Sorber¹, Afifah Suaimi¹

Institution(s): 1. University of Wyoming

Contributing team(s): KELT (Kilo-degree Extremely Little Telescope)

120.10 – The Maximum Mass of a Planet

Giant planet occurrence is a steeply increasing function of FGK dwarf host star metallicity, and this is interpreted as support for the core-accretion model of giant planet formation. On the other hand, the occurrence of low-mass stellar companions to FGK dwarf stars does not appear to depend on stellar metallicity. The mass at which objects no longer prefer metal-rich FGK dwarf host stars can therefore be used to infer the maximum mass of objects that form like planets through core accretion. I’ll show that objects more massive than about 10 M_Jup do not orbit metal-rich host stars and that this transition is coincident with a minimum in the occurrence rate of such objects. These facts suggest that the maximum mass of a celestial body formed through core accretion like a planet is less than 10 M_Jup. This observation can be used to infer the properties of protoplanetary disks and reveals that the Type I and Type II disk migration problems---two major issues for the modern model of planet formation---are not problems at all.

Author(s): Kevin C Schlaufman¹

Institution(s): 1. Johns Hopkins University

Furthermore, there are rarely robust constraints on the time-resolved dynamics in the white-light emitting flare layers. We are conducting a statistical study of the properties of Fe II lines, Mg II lines, and NUV continuum intensity in bright flare kernels observed by the Interface Region Imaging Spectrograph (IRIS), in order to provide comprehensive constraints for radiative-hydrodynamic flare models. Here we present a new technique for
121.03 – Developing methods of determining unknown rotational periods of asteroids via observations of (3122) Florence by the Harvard Observing Project

(3122) Florence is an asteroid that made the headlines with its close approach to Earth in late 2017. It is one of the biggest and brightest near-Earth asteroids that has been discovered and it has recently been found to have two moons. By observing the light reflected off an asteroid, we can measure its brightness over time and determine the rotational period of the asteroid. An asteroid’s rotational period can reveal information about its physical characteristics, such as its shape, and further our knowledge about processes that contribute to asteroid rotation in general. The Harvard Observing Project (HOP) is an initiative that allows undergraduates to learn about observational astronomy and take part in formal data collection and analysis. Over the course of the fall 2017 semester, HOP obtained four multi-hour, continuous observations in the R-band of the asteroid using the Harvard University 16-inch Clay Telescope. In our analysis, we reduced the images and performed astrometry and photometry on the data. The asteroid’s light curve was produced using AstroImageJ and we used the Python package gatsby to determine its rotational period. We found the rotational period to be 2.22 hours +/- 0.25, which agrees with the known rotational period of 2.3580 hours +/- 0.0002. This spring 2018 semester we are applying our methods to data collected on asteroids with unknown rotational periods and plan to present our findings.

Author(s): Natasha Sarah Abrams¹, Allyson Bieryla¹, Sebastian Gomez1, Jane Huang¹, John Lewis¹, Zoe Todd¹, Munazza Alam¹, Theron Carmichael¹, Lehman H Garrison¹, Ian Weaver¹, Chen Chen¹, Chima McGruder¹, Amber Medina¹
Institution(s): 1. Harvard University

121.04 – Dynamical Circularization of the Martian Orbit

As part of an investigation into the history of the orbital characteristics of the planet Mars, in conjunction with research being performed by Cole Brown and Dr. Darren Williams, I have run dynamical computer simulations of the solar system placing the eccentricity of the Martian orbit between 0.2 and 0.4 in order to discern the viability of eccentricity damping due to long-range planetary interactions as well as interactions with swarms of asteroids placed randomly between 0.5-2.0 AU. This research is one component of a hypothesis intended to explain the geological evidence of flowing water on the primordial Martian surface.

Author(s): Quinn Patrick Bierbaum¹, Cole Brown¹, Darren M. Williams¹
Institution(s): 1. Penn State, Erie

122 – Education iPoster Session

122.01 – Noyce SWARMS Scholars and Two Professional Development Models (LASSI and RAMPED): Summer 2015, 2016, and 2017

This poster showcases an astronomy professional development (PD) for 41 K-12 teachers. The project was entitled Launching Astronomy Standards and STEM Integration (LASSI). A project description (activities in the 18 months - Summer 2015 and 2016) for the astronomy, authentic science, and pre-service teacher opportunities is included. The PD team utilized real-world problems, participant-generated questions, science instruments, technology, evidence, communication, dissemination, and collaboration in the LASSI PD model. Computer science was a feature of the PD and the K-12 teacher participants showcased various methods of its use. Embracing an engineering process with an authentic astronomy PD allowed participants to make connections to current topics and create shareable projects. The PD team highlights teacher work from LASSI entitled - A Model for Determining Size of Objects in an Artificial Solar System. The Sustaining Wyoming’s Advancing Reach in Mathematics and Science (SWARMS) Scholars (NSF Noyce funded) interacted with and used the materials from the LASSI PD. The poster highlights PD use from the LASSI participants and SWARMS Scholars as well as explains lessons learned to date as a follow-up PD Robotics, Applied Mathematics, Physics, and Engineering Design (RAMPED) was implemented in Summer 2017 and carried methods from LASSI. The LASSI and RAMPED PD teams included faculty from the College of Education, College of Engineering and Applied Science, College of Arts and Sciences, graduate students, and the teachers themselves. The PD teams created a website with these and other PD materials - UWpd.org - for others to view and change to meet their needs.

Author(s): Andrea C Burrows¹, Adam D. Myers¹, Mike Borowczak¹
Institution(s): 1. University of Wyoming

122.02 – Embracing Diversity: The Exploration of User Motivations in Citizen Science Astronomy Projects

Online citizen science projects ask members of the public to donate spare time on their personal computers to process large datasets. A critical challenge for these projects is volunteer recruitment and retention. Many of these projects use Berkeley Open Infrastructure for Network Computing (BOINC), a piece of middleware, to support their operations. This poster analyzes volunteer motivations in two large, BOINC-based astronomy projects, Einstein@Home and Milkyway@Home. Volunteer opinions are addressed to assess whether and how competitive elements, such as credit and ranking systems, motivate volunteers. Findings from a study of project volunteers, comprising surveys (n=2,031) and follow-up interviews (n=21), show that altruism is the main incentive for participation because volunteers consider scientific research to be critical for humans. Multiple interviewees also revealed a passion for extrinsic motivations, i.e. those that involve recognition from other people, such as opportunities to become co-authors of publications or to earn financial benefits. Credit and ranking systems motivate nearly half of interviewees. By analyzing user motivations in astronomical BOINC projects, this research provides scientists with deeper understandings about volunteer communities and various types of volunteers. Building on these findings, scientists can develop different strategies, for example, awarding volunteers badges, to recruit and retain diverse volunteers, and thus enhance long-term user participation in astronomical BOINC projects.

Author(s): Lo Lee
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122.03 – Undergraduate Planet Hunters: Tools and Results

One student "Honors Experience" option at Florida Gulf Coast University is a research experience, and we have developed a "Planet Hunters" course to provide an astronomical research track that satisfies that requirement. Students spend the first semester learning astronomical background and exoplanet detection techniques, while the second semester is primarily devoted to planet searches in K2 data using student-oriented software tools developed specifically for the task. In this poster, we illustrate those tools and show results obtained by class participants during this years experience.
122.04 – Mercury in Retrograde: Shaking Up the Study of Orbital Motion with Kinesthetic Learning

We are investigating the use of kinesthetic activities to teach the orbital motion of planets at the introductory astronomy level. In addition to breaking the monotony of traditional classroom settings, kinesthetic activities can allow novel connections to form between the student and the material, as established in a recent study. In our example active learning activity, two students walk along predetermined paths in the classroom, simulating the dynamics of any two real or fictional bodies in orbital motion about a common object. Each student carries a short-range, local positioning device that records its 2D position, continuously. The position data from both devices are collected on a single computer. After acquisition, the data can be used to highlight interesting features of orbital dynamics. For example, we demonstrate a particular transformation of the data that shows apparent retrograde motion arising directly from the relative motion of two bodies orbiting a common object. This activity provides students with the opportunity to observe interesting orbital dynamics on a human scale.

Author(s): Paul DeStefano¹, Thomas Allen¹, Ralf Widenhorn¹
Institution(s): 1. Portland State University

122.05 – Actively Learning about the Active Sun: Using JHelioviewer in Undergraduate Astronomy

Solar phenomena of the chromosphere, corona and photosphere are only truly revealed through multi-wavelength and time-dependent study. While one can show slides of models of the solar convection zone, videos of granulation, and magnetogram and UV images, it is now possible to engage students much more fully in learning about dynamic solar phenomena such as the evolution of sunspots and the magnetic field. JHelioviewer is professional solar visualization tool developed by an international team as part of the ESA/NASA Helioviewer project (Muller et al., 2017, AKA 606, A10), which allows users to select and overlay movies of solar data from multiple instruments of multiple satellite and ground-based observatories, with complete control over time-sequencing, image overlays, solar coordinate grids, rotational tracking, and export functions. I developed materials using the viewer for my sophomore-level undergraduate solar astronomy course to introduce students to the dynamics of the solar surface and atmosphere. The lab-like projects, suitable for in-class, labs, or home-work assignments, allow students to watch the formation, strengthening, movement, and dissipation of sunspots; to classify spots; to study the magnetic flux tubes connecting spots; to see reconnection; to learn about the solar coordinate systems (Stonyhurst, Carrington, etc.); to see how line emission (H-alpha, C, Fe and He UV lines from SDO, etc.) traces the structure of the atmosphere at different heights and temperatures; to observe the Wilson effect; and to measure motions such as moat flow and photospheric flow by tracking individual elements in magnetograms. In this presentation I share my activities and approach, which can be tailored to suit gen-ed, intermediate, or advanced astrophysics majors. (The author has no connection with the JHelioviewer project or team.)

Author(s): Derek L. Buzasi¹, Lindsey Carbonneau¹, Laura Ferrell¹, Gilbert Green¹, Maya Kaiser¹, Kira Kreke¹, Samantha Lundy¹, William Merritt¹, Matlin Passino¹, Harrison Paxton¹, Alexandra Podaril¹, Alexis Stansfield¹
Institution(s): 1. Florida Gulf Coast University

122.06 – Undergraduate Research Program Between SCU and SOFIA

We present results on an undergraduate research program run in collaboration between Santa Clara University (SCU), a predominately undergraduate liberal arts college and the SOFIA Science Center/USRA. We have started a synergistic program between SCU and SOFIA (located at NASA Ames) where the students are able to be fully immersed in astronomical research; from helping to write telescope observing proposal; to observing at a world-class telescope; to reducing and analyzing the data that they acquired and ultimately to presenting/publishing their findings. A recently awarded NSF collaborative grant will allow us to execute and expand this program over the next several years. In this poster we present some of our students research and their success after the program. In addition, we discuss how a small university can actively collaborate with a large government-funded program like SOFIA, funded by NASA.

Author(s): Kristin Rose Kulas¹, B-G Andersson²
Institution(s): 1. Santa Clara University, 2. USRA

122.07 – Astronomy Research Seminars

Astronomy Research Seminars are offered by a rapidly growing number of community colleges and universities. Over the past decade some 120 student team research papers have been published with approximately 500 coauthors. Each team manages their own research, obtains and analyzes original data, writes a team paper, obtains an external review, submits their paper for publication, and gives a public PowerPoint presentation. The student teams are supported by: (1) an extensive community-of-practice which consists of professional and amateur astronomers, educators, and Seminar graduates; (2) the Institute for Student Astronomical Research (www.in4star.org); (3) the Small Telescope Astronomy Research Handbook; and (4) an in-person/online, open-source Canvas learning management system with videos, quizzes, and other, extensive supporting material. Team research projects are completed in a semester or less and are managed by the students themselves. The Seminars have expanded from double star astronomy to asteroid astrometry, eclipsing binary times of minima, and exoplanet transits. Conducting authentic research inspires students, provides them with important skills in teamwork, project management and scientific literacy, and gives them confidence in their abilities to participate in scientific research. Being coauthors of published papers boosts student educational careers with respect to admissions and scholarships.

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123 – The Sun & Solar System iPoster Session

123.01 – Study of the Asteroid Florence

Asteroid Florence was discovered at Siding Spring Observatory in Australia (March 1981). Paul Chodos, manager of CNEOS-JPL said: “Florence is the largest asteroid to pass by our planet this close since the NASA program to detect and track near-Earth asteroids began” [1]. The asteroid passed 7.1 million kilometers away from the earth [2]. The GDSCC-NASA discovered that the asteroid has two small moons. The diameter of Florence is 4.5 kilometers, and the sizes of the two moons are probably between 100 – 300 meters across. The larger moon has a rotation period around Florence of about 8 hours, and the outer moon has a period of about 25 hours [3]. From our Observatory, located in Pasto-Colombia, we captured several pictures, videos and astrometry data during several hours during three days. Our data was published by the Minor Planet Center (MPC) and also appears at the web page of NEOdyS [4]. The pictures were captured with the following equipment: CGE PRO 1400 CELESTRON and STL-1001 SBIG camera. Astrometry and photometry was carried out, and we calculated the orbital elements and the rotation period. Summary and conclusions: We obtained the following orbital parameters: eccentricity = 0.422548 +/- 0.000994, semi-major axis = 1.76675 +/- 0.00313 A.U, orbital inclination = 0.422548 +/- 0.029 deg, longitude of the ascending node = 336.0960 +/- 0.0013 deg, argument of perihelion = 27.861 +/- 0.016, mean motion = 0.41970 +/- 0.00112 deg/d, perihelion distance = 1.0202151 +/- 0.000994, perihelion distance = 1.0202151 +/- 0.000994.
aphelion distance = 2.51329 +/- 0.00625 A.U. absolute magnitude = 14.4. The parameters were calculated based on 281 observations. Dates: 2017 September 01 to 05 with mean residual = 0.19 arcseconds. The asteroid has an orbital period of 2.35 years (857.74 days). The rotation period of the asteroid is 2.3 hours. Note: Spaceweather published our video on September 1-2017 [5].


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Institution(s): 1. University of Narino Observatory

123.02 – Titan’s Oxygen Chemistry and its Impact on Haze Formation

Though Titan’s atmosphere is reducing with its 98% N2, 2% CH4 and 0.1% H2, CO is the fourth most abundant molecule with a uniform mixing ratio of ~50 ppm. Two other oxygen bearing molecules have also been observed in Titan’s atmosphere: CO2 and H2O, with a mixing ratio of ~15 and ~1 ppb, respectively. The physical and chemical processes that determine the abundances of these species on Titan have been at the centre of a long-standing debate as they place constraints on the origin and evolution of its atmosphere. Moreover, laboratory experiments have shown that oxygen can be incorporated into complex molecules, some of which are building blocks of life. Finally, the presence of CO modifies the production rate and size of tholins, which transposed to Titan’s hazy atmosphere may have some strong repercussions on the temperature structure and dynamics of the atmosphere.

We present here our current understanding of Titan’s oxygen chemistry and of its impact on the chemical composition of the haze. We base our discussion on state-of-the-art laboratory experiments for the synthesis and chemical analysis of aerosol analogues. We used a very-high resolution mass spectrometer (LTQ-Orbitrap XL instrument) to characterize the soluble part of tholin samples generated from N2/CH4/CO mixtures at different mixing ratios. These composition measurements provide some understanding of the chemical mechanisms by which CO co-precipitates particle formation and growth. Our final objective is to obtain a global picture of the fate and impact of oxygen on Titan, from its origin to prebiotic molecules to haze particles to material deposited on the surface.

Author(s): Veronique Vuitton2, Chao He1, Sarah Moran1, Cedric Wolters2, Laurene Flandinet2, Francois-Regis Orthous-Daunay3, Roland Thissen3, Sarah Horst1

123.03 – ALMA Thermal Mapping of Ceres – Search for Subsurface Water Ice

Spectroscopic observations of the surface of Ceres by Dawn have demonstrated that hydrated minerals are ubiquitous, but only few smaller sites are enriched with water ice. This is somewhat surprising as Ceres is believed to host a large amount of water in its interior.

The possibility of inhomogeneous subsurface water distribution can be investigated by tracing thermal inertia features. To that effect, we mapped the temperature of Ceres using 1.3mm maps of the whole surface obtained with the Atacama Large Millimeter Array (ALMA) over three different epochs during one Ceres’ year. Assessing the thermal conditions at the depths probed by sub millimeter observations (a few cm below the surface, within the annual thermal skin depth) is critical to constrain the effective thermal inertia, and hence the status of subsurface water ice. We will present preliminary results in terms of temperature features and the corresponding thermal inertia derived based on comparisons from the KRC thermal model which has been extensively used for Mars. Initial analysis is consistent with the presence of near-surface high thermal inertia layer, presumably water ice, in the north polar region.

This work is supported by the NASA Solar System Observations Program NNX15AE02G.

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123.04 – On The Detachment of Massive Trans-Neptunian Objects

Our Solar System contains a large population of icy bodies stretching well beyond the orbit of Neptune. These objects, known collectively as the Scattered Disk, are remnants from the early formation of the Solar System that were scattered outward from their birth location by Neptune. But not all fit the bill.

Sedna, one particularly massive Trans-Neptunian Object (TNO), does not conform to the scattering pattern. Its orbital eccentricity (e) is much lower than expected for a scattered object. This means its perihelion distance (proportional to 1-e) is much larger than the orbit of Neptune, or that it is “detached” from the main Solar System. Many more TNOs share similarities with Sedna. These observations suggest that there is a large population of detached TNOs that have a dynamical history different than that of the objects scattered by Neptune.

The physical mechanism by which these massive minor planets become detached is currently unknown. However, we have discovered a phenomenon, driven by differential precession between TNOs of different masses and mutual secular gravitational torques, that naturally detach massive minor planets. This mechanism could have notable consequences for the outer Solar System and may shed some light on the origin of the detached population of minor planets near the Scattered Disk.

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Institution(s): 1. University of Colorado at Boulder

123.05 – Experimental testing of scattering polarization models

We realized a laboratory experiment to study the polarization of the Na I doublet at 589.3 nm, in the presence of a magnetic field. The purpose of the experiment is to test the theory of scattering polarization for illumination conditions typical of astrophysical plasmas. This work was stimulated by solar observations of the Na I doublet that have proven particularly challenging to reproduce with current models of polarized line formation, even casting doubts on our very understanding of the physics of scattering polarization on the Sun. The experiment has confirmed the fundamental correctness of the current theory, and demonstrated that the “enigmatic” polarization of those observations is exclusively of solar origin.

Author(s): Wenxian Li2, Roberto Casini2, Steven Tomczyk2, Egidio Landi Degl’Innocenti3, Branan Marsell3

123.06 – Solar g-modes? Comparison of detected asymptotic g-mode frequencies with solar model predictions

After many years of searching for solar gravity modes, Fossat et al. (2017) reported detection of the nearly equally spaced high-order g-modes periods using a 15-year time series of GOLF data from the SOHO spacecraft. Here we report progress towards and challenges associated with calculating and comparing g-mode period predictions for several previously published standard solar
models using various abundance mixtures and opacities, as well as the predictions for some non-standard models incorporating early mass loss, and compare with the periods reported by Fossat et al (2017). Additionally, we have a side-by-side comparison of results of different stellar pulsation codes for calculating g-mode predictions. These comparisons will allow for testing of nonstandard physics input that affect the core, including an early more massive Sun and dynamic electron screening.

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123.07 – Configuration of and Motions in the Solar Corona at the 2017 Total Solar Eclipse

We report on high-contrast data reduction of white-light images from the August 21, 2017, total solar eclipse. We show the configuration of the solar corona at this declining phase of the solar-activity cycle, with the projection onto the plane of the sky of the three-dimensional coronal streamers plus extensive polar plumes. We discuss the relation of the white-light coronal loops visible in our observations with extreme-ultraviolet observations from NASA’s Solar Dynamics Observatory Atmospheric Imaging Assembly (AIA) and NOAA’s GOES-16 Solar Ultraviolet Imager (SUVI). We show differences and motions over a 65-minute interval between observations from our main site at Willamette University in Salem, Oregon, and a subsidiary site in Carbondale, Illinois. We discuss, in particular, a giant demarcation about 1 solar radius outward in the southwest that crosses the radial streamers.

Our observations of the eclipse were sponsored in large part by the Committee for Research and Exploration of the National Geographic Society and by the Solar Terrestrial Program of the National Geographic Society. Additional support was received from the NASA Massachusetts Space Grant Consortium, the Sigma Xi honorary scientific society, the University of Pennsylvania (for DS), the Slovak Academy of Sciences VEGA project 2/0003/16, and the Freeman Foote Expeditionary and Brandi funds at Williams College. We thank Stephen Thorsett, Rick Watkins, and Honey Wilson of Willamette University for their hospitality. See http://totalsolareclipse.org or http://sites.williams.edu/eclipse/2017-usa/.

124 – Extrasolar Planets iPoster Session

124.01 – Lyman-alpha transit observations of the warm rocky exoplanet GJ1132b

GJ1132b is one of the few known Earth-sized planets, and at 12pc away it is also one of the closest known transiting planets. With an equilibrium temperature of 500 K, this planet is too hot to be habitable but we can use it to learn about the presence and volatile content of rocky planet atmospheres around M dwarf stars. Using Hubble STIS spectra obtained during primary transit, we search for a Lyman-$\alpha$ transit. If we were to observe a deep Lyman-$\alpha$ transit, that would indicate the presence of a neutral hydrogen envelope flowing from GJ1132b. On the other hand, ruling out deep absorption from neutral hydrogen may indicate that this planet has either retained its volatiles or lost them very early in the star’s life. We carry out this analysis by extracting 1D spectra from the STIS pipeline, splitting the time-tagged spectra into higher resolution samples, and producing light curves of the red and blue wings of the Lyman-$\alpha$ line. We fit for the baseline stellar flux and transit depths in order to constrain the characteristics of the cloud of neutral hydrogen gas that may surround the planet. We do not conclusively detect a transit but the results provide an upper limit for the transit depth. We also analyze the stellar variability and Lyman-$\alpha$ spectrum of GJ1132, a slowly-rotating 0.18 solar mass M dwarf with previously uncharacterized UV activity. Understanding the role that UV variability plays in planetary atmospheres and volatile retention

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123.08 – The Coincident Coherence of Extreme Doppler Velocity Events with p-mode Patches in the Solar Photosphere.

Observations of the solar photosphere show many spatially compact Doppler velocity events with short life spans and extreme values. In the 1MaX spectropolarimetric inversion data of the first flight of the SUNRISE balloon in 2009 these striking flashes in the intergranule lanes and complementary outstanding values in the centers of granules have line of sight Doppler velocity values in excess of 4 sigma from the mean. We conclude that values outside 4 sigma are a result from the superposition of the granulation flows and the p-modes.

To determine how granulation and p-modes contribute to these outstanding Doppler events, I separate the two components using the Fast Fourier Transform. I produce the power spectrum of the spatial wave frequencies and their corresponding frequency in time for each image, and create a k-omega filter to separate the two components. Using the filtered data, test the hypothesis that extreme events occur because of strict superposition between the p-mode Doppler velocities and the granular velocities. I compare event counts from the observational data to those produced by random superposition of the two flow components and find that the observational event counts are consistent with the model event counts in the limit of small number statistics. Poisson count probabilities of event numbers observed are consistent with expected model count probability distributions.

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is crucial to assess atmospheric evolution and the habitability of cooler rocky planets.

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Contributing team(s): Will

124.02 – Did A Planet Survive A Post-Main Sequence Evolutionary Event?

The GL86 star system approximately 10 pc away with a main sequence K type ~0.77 M\(_{\odot}\) star (GL86A) with a white dwarf ~0.49 M\(_{\odot}\) companion (GL86B). The system has a ~18.4 AU semi-major axis, an orbital period of ~353 yrs, and an eccentricity of ~0.39. A 4.5 M\(_{\oplus}\) planet orbits the main sequence star with a semi-major axis of 0.113 AU, an orbital period of 15.76 days, in a near circular orbit with an eccentricity of 0.046. If we assume that this planet was formed during the time when the white dwarf was a main sequence star, it would be difficult for the planet to have remained in a stable orbit during the post-main sequence evolution of GL86 B. The post-main sequence evolution with planet survival will be examined by modeling using the program Mercury (Chambers 1999). Using the model, we examine the origins of the planet: whether it formed before or after the post-main sequence evolution of GL86B. The modeling will give us insight into the dynamical evolution of, not only, the binary star system, but also the planet’s life cycle.

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124.03 – Fast Coherent Differential Imaging for Exoplanet Imaging

Direct detection and detailed characterization of exoplanets using extreme adaptive optics (ExAO) is a key science goal of future extremely large telescopes and space observatories. However, quasi-static wavefront errors will limit the sensitivity of this endeavor. Additional limitations for ground-based telescopes arise from residual AO-corrected atmospheric wavefront errors, generating short-lived aberrations that will average into a halo over a long exposure, also limiting the sensitivity of exoplanet detection. We develop the framework for a solution to both of these problems using the self-coherent camera (SCC), to be applied to ground-based telescopes, called Fast Atmospheric SCC Technique (FAST). Simulations show that for typical ExAO targets the FAST approach can reach ~100 times better in raw contrast than what is currently achieved with ExAO instruments if we extrapolate for an hour of observing time, illustrating that the sensitivity improvement from this method could play an essential role in the future ground-based detection and characterization of lower mass/colder exoplanets.

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124.05 – Correcting Estimates of the Occurrence Rate of Earth-like Exoplanets for Stellar Multiplicity

One of the most prominent questions in the exoplanet field has been determining the true occurrence rate of potentially habitable Earth-like planets. NASA’s Kepler mission has been instrumental in answering this question by searching for transiting exoplanets, but follow-up observations of Kepler target stars are needed to determine whether or not the surveyed Kepler targets are in multi-star systems. While many researchers have searched for companions to Kepler planet host stars, few studies have investigated the larger target sample. Regardless of physical association, the presence of nearby stellar companions biases our measurements of a system’s planetary parameters and reduces our sensitivity to small planets. Assuming that all Kepler target stars are single (as is done in many occurrence rate calculations) would overestimate our search completeness and result in an underestimate of the frequency of potentially habitable Earth-like planets. We aim to correct for this bias by characterizing the set of targets for which Kepler could have detected Earth-like planets.

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124.06 – The Colorado Ultraviolet Transit Experiment (CUTE): Observing Mass Loss on Short-Period Exoplanets

The Colorado Ultraviolet Transit Experiment (CUTE) is an NUV spectrophotograph packaged into a 6U CubeSat, designed to characterize the interaction between exoplanetary atmospheres and their host stars. CUTE will conduct a transit spectroscopy survey, gathering data over multiple transits on more than 12 short-period exoplanets with a range of masses and radii. The instrument will characterize the spectral properties of the transit light curves to <1% depth sensitivity. The NUV is host to several high oscillator strength atomic and molecular absorption features predicted to exist in the upper atmospheres of these planets, including Mg I, Mg II, Fe II, and OH. The shape and evolution of these spectral light curves will be used to quantify mass loss rates, the stellar drives of that mass loss, and the possible existence of exoplanetary magnetic fiends. This poster presents the science motivation for CUTE, planned observation and data analysis methods, and expected results.

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124.07 – Impact of clouds in the JWST and LUVOIR simulated transmission spectra of TRAPPIST-1 planets in the habitable zone

M-dwarfs are the most common type of stars in our galaxy. Ultra-cool dwarfs (T < 2700 K) are a sub-stellar class of late M-dwarfs and represent nearly ~15% of astronomical objects in the stellar neighborhood of the Sun. Their smaller size than regular M-dwarfs allows easier detection of rocky exoplanets in close orbits, and this potential was recently realized by the discovery of the TRAPPIST-1 system. Located about 12 pc away, TRAPPIST-1 has seven known planets, and it is one of the most promising rocky-planet systems for follow-up observations due to the depths of the transit signals. Transit-timing variation (TTVs) measurements of the TRAPPIST-1 planets suggest terrestrial or volatile-rich composition. Also, it has been found that three planets (TRAPPIST-1 e, f, and g) are in the Habitable Zone (HZ) where surface temperatures would allow surface water to exist. These planets will be prime targets for atmospheric characterization with JWST owing to their relative proximity to Earth and frequent planetary transits.

Atmospheric properties are major components of planet habitability. However, the detectability of gaseous features on rocky planets in the HZ may be severely impacted by the presence of clouds and/or hazes in their atmosphere. We have already seen
this phenomenon in the “flat” transit transmission spectra of larger exoplanets such as GJ 1214b, WASP-31b, WASP-12b and HATP-12b.

In this work, we use the LMDG global climate model to simulate several possibilities of atmospheres for TRAPPIST-1 e, f and g: 1) Archean Earth, 2) modern Earth and 3) CO2-dominated atmospheres. We also calculate synthetic transit spectra using the GSFC Planetary Spectrum Generator (PSG), and determine the number of transits needed to observe key spectral features for both JWST and future telescopes (ARIEL, LUVOIR, HabEx). We will identify differences in the spectra of cloudy vs non-cloudy, and determine how much information on spatial variability in atmospheric characteristics can be extracted from time-resolved transit and eclipse mapping. A particular attention will be given to the impact of the atmospheric variability when adding transit spectra, and how this may affect atmospheric parameter retrievals.

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125 – Instrumentation: Space and Ground iPoster Session

125.01 – The Observing Modes of JWST/NIRISS

The Near Infrared Imager and Slitless Spectrograph (NIRISS) is a contribution of the Canadian Space Agency to the James Webb Space Telescope (JWST). NIRISS complements the other near-infrared science instruments onboard JWST by providing capabilities for (a) low resolution grism spectroscopy between 0.8 and 2.2 µm over the entire field of view, with the possibility of observing the same scene with orthogonal dispersion directions to disentangle blended objects; (b) medium-resolution grism spectroscopy between 0.6 and 2.8 µm that has been optimized to provide high spectrophotometric stability for time-series observations of transiting exoplanets; (c) aperture masking interferometry that provides high angular resolution of 70 - 400 mas at wavelengths between 2.8 and 4.8 µm; and (d) parallel imaging through a set of filters that are closely matched to NIRCam’s.

In this poster, we discuss each of these modes and present simulations of how they might typically be used to address specific scientific questions.

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Contributing team(s): NIRISS Team

125.02 – Updates on the Performance and Calibration of HST/STIS

The Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope (HST) has been in orbit for 21 years and continues to produce high quality scientific results using a diverse complement of operating modes. These include spatially resolved spectroscopy in the UV and optical, high spatial resolution echelle spectroscopy in the UV, and solar-blind imaging in the UV. In addition, STIS possesses unique visible-light coronagraphic modes that keep the instrument at the forefront of exoplanet and debris-disk research. As the instrument’s characteristics evolve over its lifetime, the instrument team at the Space Telescope Science Institute monitors its performance and works towards improving the quality of its data products. Here we present updates on the status of the STIS CCD and FUV & NUV MAMA detectors, as well as changes to the CallSTIS reduction pipeline.

We also discuss progress toward the recalibration of the E140M/1425 echelle mode. The E140M grating blaze function shapes have changed since flux calibration was carried out following SM4, which limits the relative photometric flux accuracy of some spectral orders up to 5-10% at the edges. In Cycle 25 a special calibration program was executed to obtain updated sensitivity curves for the E140M/1425 setting.

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125.03 – The Maunakea Spectroscopic Explorer

The Maunakea Spectroscopic Explorer (MSE) is an ambitious project to transform the Canada-France-Hawaii 3.6-metre telescope into an 11.25-metre facility dedicated to wide field multi-object spectroscopy. Following a successful conceptual design review of ten subsystems and the systems-level review in January 2018, MSE is preparing to move into the Preliminary Design Phase. MSE will simultaneously deploy over 3000 fibers that feed low/medium resolution spectrometers and 1000 fibers that feed high-resolution (R~40,000) spectrometers. This design is expected to revolutionize astrophysical studies requiring large spectroscopic datasets; i.e., reconstructing the Milky Way’s formation history through the chemical tagging of stars, searches for the effects of dark matter on stellar streams, determination of environmental influences on galaxy formation since cosmic noon, measuring black hole masses through repeat spectroscopy of quasars, follow-up of large samples identified in other surveys (Gaia, LSST, SKA, etc.), and more. MSE will reuse a large fraction of CFHT’s existing facilities while tripling the diameter of the telescope’s primary mirror and increasing the height of the enclosure by only 10%. I will discuss the progress to date and opportunities for partnerships.

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125.04 – Robotic Software for the Thacher Observatory

The Thacher Observatory—a research and educational facility located in Ojai, CA—uses a 0.7 meter telescope to conduct photometric research on a variety of targets including eclipsing binaries, exoplanet transits, and supernovae. Currently, observations are automated using commercial software. In order to expand the flexibility for specialized scientific observations and to increase the educational value of the facility on campus, we are adapting and implementing the custom observatory control

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software and queue scheduling developed for the Miniature Exoplanet Radial Velocity Array (MINERVA) to the Thacher Observatory. We present the design and implementation of this new software as well as its demonstrated functionality on the Thacher Observatory.

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125.05 – Taeduk Radio Astronomy Observatory and Key Science Programs

Taeduk Radio Astronomy Observatory (TRAO) is now equipped with a new main control computer with VxWorks operating system, a new receiver system, and a new backend system. The receiver system(SEQUOIA-TRAO) is equipped with high-performing 16-pixel MMIC pre-amplifiers in a 4x4 array, operating within 85–115 GHz frequency range. The system temperature ranges from 150 K(85 GHz) to 400 K(115 GHz). The 2nd IF modules with the narrow band and the 8 channels with 4 FFT spectrometers allow to observe 2 frequencies simultaneously within the 85–100 or 100–115 GHz bands for all 16 pixels. Radome replacement was completed successfully in February 2017. In addition, a new servo system was installed in 2017 autumn season, providing faster and more stable tracking mode of the telescope. Thus we can save telescope time at least 10%. We are providing OTF(On-The-Fly) as a main observing mode, and position switching mode is available as well. The backend system(FFT spectrometer) provides the 406x62 channels with fine velocity resolution of about 0.05 km/sec(15 kHz) per channel, and their full spectra bandwidth is 60 MHz. Beam efficiency of the TRAO was measured to be about 48% - 54% (with less than 2% error) between 85 and 115 GHz frequency range. The pointing errors of the 14m telescope were found be 4.4 arcsec in AZ direction and 6 arcsec in EL direction. Generally, we allocate 18 hours of telescope time a day from January to the middle of May, and from October to December. Three Key Science Programs had been selected in 2015 fall and they are supposed to have higher priority for telescope time, up to 50%. General proposals from enthusiastic mm-wave astronomers from any country are encouraged.

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125.06 – Investigating the Impact of a Solar Eclipse on Atmospheric Radiation

126 – Astronomy in Denver iPoster Session

126.01 – Astronomy in Denver: Spatial distributions of dust properties via far-IR broadband map with HerPlaNS

We present the results of our analyses on dust properties in all of Galactic planetary nebulae based on 5-band broadband images in the far-IR taken with the Herschel Space Observatory.

By fitting surface brightness distributions of dust thermal emission at 70, 160, 250, 350 and 500 microns with a single-temperature modified black body function, we derive spatially resolved maps of the dust emissivity power-law index (beta) and dust temperature (Td), as well as the column density.

We find that circumstellar dust grains in PNe occupy a specific region in the beta-Td space, which is distinct from that occupied by dust grains in the Interstellar Matter (ISM) and star forming regions (SFRs). Unlike those in the ISM and SFRs, dust grains in PNe exhibit little variation in beta while a large spread in Td, suggesting rather homogeneous dust properties.

This work is part of the Herschel Planetary Nebula Survey Plus

We present a project that measured atmospheric muon flux as a function of altitude during a total solar eclipse. An auxiliary goal was to design and build a cost-effective muon detection device that is simple enough for those with minimal training to build. The detector is part of a self-contained autonomous payload that is carried to altitude aboard a weather balloon. The detection system consists of three Geiger counters connected to a coincidence circuit. This system, along with internal and external temperature sensors and an altimeter, are controlled by an on-board Arduino Mega microcontroller. An internal frame was constructed to house and protect the payload components using modular 3D-printed parts. The payload was launched during the 2017 solar eclipse from Guernsey, Wyoming, along the path of totality. Initial data analysis indicates that line-of-sight blockage of the sun due to a total eclipse produces a negligible difference in muon flux when compared to the results of previous daytime flights. The successful performance of the payload, its low overall cost, and its ease of use suggest that this project would be well-suited for individuals or groups such as high school or undergraduate science students to reproduce and enhance.

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125.07 – Updates to WFC3/UVIS Filter-Dependent and Filter-Distinct Distortion Corrections

The WFC3/UVIS filter wheel contains 63 filters that cover a large range of wavelengths from near ultraviolet to the near infrared. Previously, analysis was completed on the 14 most used UVIS filters to calibrate geometric distortions. These distortions are due to a combination of the optical assembly of HST as well as the variabilities in the composition of individual filters. We report recent updates to reference files that aid in correcting for these distortions of an additional 22 UVIS narrow and medium band filters and 4 unique UVIS filters. They were created following a calibration of the large-scale optical distortions and fine-scale filter-dependent distortions. Furthermore, we present results on a study into a selection of unique polynomial coefficient terms from all solved filters which allows us to better investigate the filter-dependent patterns across a large range of wavelengths.

These updates will provide important enhancements for HST/WFC3 users as they allow more accurate alignment of images across the range of UVIS filters.

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(125.05 – Taeduk Radio Astronomy Observatory and Key Science Programs)

126.02 – Astronomy in Denver: Probing Interstellar Circular Polarization with Polvis, a Full Stokes Single Shot Polarimeter

Measurements of optical circular polarization (Stokes V) introduced by dust grains in the ISM are important for two main reasons. First of all, the polarization itself contains information about the metallic versus dielectric composition of the dust grains themselves (H. C. van de Hulst 1957, textbook). Additionally, circular polarization can help constrain the interstellar component of the polarization of any source that may have intrinsic polarization, which needs to be calibrated for astrophysical study. Though interstellar circular polarization has...
been observed (P. G. Martin 1972, MNRAS 150), most broadband measurements of ISM polarization include linear polarization only (Stokes Q and U), due to the relatively low circular polarization signal and the added instrumentation complexity of including V-measurement capability. Prior circular polarization measurements have also received very little follow-up in the past several decades, even as polarimeters have become more accurate due to advances in technology. The University of Denver is pursuing these studies with POLVIS, a prototype polarimeter that utilizes a stress-engineered optic ("SEO", A. K. Spilman and T. G. Brown 2007, Applied Optics 46) to produce polarization-dependent PSFs (A. M. Beckley and T. G. Brown 2010, Proc SPIE 7570). These PSFs are analyzed to provide simultaneous Stokes I, Q, U, and V measurements, in a single beam and single image, along the line-of-sight to point source-like objects. Polvis is the first polarimeter to apply these optics and measurement techniques for astronomical observations. We present the first results of this instrument in B, V, and R wavebands, providing a fresh look at full Stokes interstellar polarization. Importantly, this set of efforts will constrain the ISM contribution to the polarization with respect to intrinsic stellar components. The authors are grateful to the estate of William Herschel Womble for the support of astronomy at the University of Denver, and for funding provided by the Mt. Cuba Astronomical Foundation.

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200 – LAD Plenary Talk: Small Interstellar Molecules and What They Tell Us, David Neufeld (Johns Hopkins University)

200.01 – Small interstellar molecules and what they tell us
Observations at ultraviolet, visible, infrared and radio wavelengths provide a wealth of information about the molecular inventory of the interstellar medium (ISM). Because of the different chemical pathways responsible for their formation and destruction, different molecules probe specific aspects of the interstellar environment. Carefully interpreted with the use of astrochemical models, they provide unique information of general astrophysical importance, yielding estimates of the cosmic ray density, the molecular fraction, the ultraviolet radiation field, and

201 – Galaxy Evolution

201.01 – Mining MaNGA for Merging Galaxies: A New Imaging and Kinematic Technique from Hydrodynamical Simulations
Merging galaxies play a key role in galaxy evolution, and progress in our understanding of galaxy evolution is slowed by the difficulty of making accurate galaxy merger identifications. Mergers are typically identified using imaging alone, which has its limitations and biases. With the growing popularity of integral field spectroscopy (IFS), it is now possible to use kinematic signatures to improve galaxy merger identifications. I use GADGET-3 hydrodynamical simulations of merging galaxies with the radiative transfer code SUNRISE, the latter of which enables me to apply the same analysis to simulations and observations. From the simulated galaxies, I have developed the first merging galaxy classification scheme that is based on kinematics and imaging. Utilizing a Linear Discriminant Analysis tool, I have determined which kinematic and imaging predictors are most useful for identifying mergers of various merger parameters (such as orientation, mass ratio, gas fraction, and merger stage). I will discuss the strengths and limitations of the classification technique and then my initial results for applying the classification to the >10,000 observed galaxies in the MaNGA (Mapping Nearby Galaxies at Apache Point) IFS survey. Through accurate identification of merging galaxies in the MaNGA survey, I will advance our understanding of supermassive black hole growth in galaxy mergers and other open questions related to galaxy evolution.

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201.02 – Three-Dimensional View of Ionized Gas Conditions in Galaxies
We present a 3D version of common emission line diagnostic diagrams used to identify the source of ionization in galaxies, and highlight interesting features in this new 3D space, which are associated with global galaxy properties. Namely, we combine the BPT and Mass-Excitation (MEx) diagrams, and apply it to a set of >300,000 galaxies from the SDSS survey. Among other features, we show that the usual “branch” of star-forming galaxies becomes a curved surface in the new 3D space. Understanding the

201.03D – Investigating Galaxy Evolution and Active Galactic Nucleus Feedback with the Sunyaev-Zel'dovich Effect
Galaxy formation is a complex process with aspects that are still very uncertain. A mechanism that has been used in simulations to successfully resolve several of these outstanding issues is active galactic nucleus (AGN) feedback, where a large amount of energy is driven outwards through a galaxy and the surrounding region by a central supermassive black hole. A promising method for directly measuring this energy is by looking at small increases in the energy of the cosmic microwave background (CMB) photons as they pass through hot gas, known as the thermal Sunyaev-Zel’dovich (tSZ) effect. I will present work done to measure the tSZ effect around a large number of 0.5 < z < 1.5 elliptical galaxies using the South Pole Telescope (SPT), Atacama Cosmology Telescope (ACT), and Planck telescope, finding signals at 1-sigma to 3-sigma confidence levels depending on the dataset and redshift range. The results are mixed, including hints at non-gravitational energy possibly due to AGN feedback. Then I will present work done to analyze these results further by comparing them to matching simulated measurements, both including and not including AGN feedback, from the large-scale Horizon-AGN and Horizon-NoAGN cosmological simulations. In these comparisons, the SPT results, which tend to have lower-mass galaxies (<5x10^11 M_Sun), favor the Horizon-AGN results at about a 1-sigma level, while the ACT results, which tend to have higher-mass galaxies (>5x10^11 M_Sun), favor the Horizon-
NoAGN results at more than a 6-sigma level. These results indicate that AGN feedback may be milder than often predicted, and they also highlight the promising nature of tSZ effect measurements and the need for further work using better data and more varied simulations.

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201.04 – Resolving molecular gas to ~500 pc in a unique star forming disk galaxy at z~2

We have resolved molecular gas in a ‘typical’ star forming disk galaxy at z~2 down to the scale of ~500 pc. Previous observations of CO and [CI] lines on larger spatial scales have revealed bulk molecular and atomic gas properties indicating that the target is a massive disk galaxy with large gas reserves. Unlike many galaxies studied at high redshift, it is undergoing modest quiescent star formation rather than bursty centrally concentrated star formation. Therefore this galaxy represents an under-studied, but cosmologically important population in the early universe. Our new observations of CO (4–3) highlight the clumpy molecular gas fuelling star formation throughout the disk. Underlying continuum from cold dust provides a key constraint on star formation rate surface densities, allowing us to examine the star formation rate surface density scaling law in a never-before-tested regime of early universe galaxies.

These observations enable an unprecedented view of the obscured star formation that is hidden to optical/UV imaging and trace molecular gas on a fine enough scale to resolve morphological traits and provide a view akin to single dish surveys in the local universe.

Author(s): Drew Brishin7, Manuel Aravena7, Jacqueline Hodge5, Chris Luke Carilli6, Emanuele Daddi1, Helmut Dannerbauer3, Dominik Riechers2, Jeff Wagg4


201.05 – Role of Turbulent Damping in Cosmic Ray Galactic Winds

Large-scale galactic winds driven by stellar feedback are one phenomenon that influences the dynamical and chemical evolution of a galaxy, pushing and redistributing material throughout the interstellar medium (ISM) and galactic halo. A detailed understanding of the exact physical mechanisms responsible for these winds is lacking. Non-thermal feedback from galactic cosmic rays (CR), high-energy charged particles accelerated in supernovae and young stars, can impact the efficiency in accelerating the wind. In the self-confinement model, CR stream along magnetic field lines at the Alfven speed due to scattering off self-excited Alfv(\text{e})n waves. However, magneto-hydrodynamic (MHD) turbulence stirred up by stellar feedback dissipates these confining waves, allowing CR to be super Alfvenic. Previous simulations relying on a simplified model of transport have shown that super-Alfv(\text{e})nic streaming of CRs can launch a stronger wind. We perform three-dimensional MHD simulations of a section of a galactic disk, including CR streaming dependent on the local environment, using a realistic model of turbulent dissipation of Alfvén waves presented in Lazarian (2016). In this implementation, the CR streaming speed can be super Alfv(\text{e})nic depending on local conditions. We compare results for Alfv(\text{e})nic and locally determined streaming, and find that gas/CR distributions and instantaneous mass loading factor of the wind are different depending on the level of turbulence.


Author(s): Francisco Holquin2, Mateusz Ruszkowski2, Alex Lazarian3, H.Y. Karen Yang3


201.06D – Resolving z~2 galaxy using adaptive coadded source plane reconstruction

Natural magnification provided by gravitational lensing coupled with Integral field spectroscopic observations (IFS) and adaptive optics (AO) imaging techniques have become the frontier of spatially resolved studies of high redshift galaxies (z>1). Mass models of gravitational lenses hold the key for understanding the spatially resolved source–plane (unlensed) physical properties of the background lensed galaxies. Lensing mass models very sensitively control the accuracy and precision of source-plane reconstructions of the observed lensed arcs. Effective source-plane resolution defined by image-plane (observed) point spread function (PSF) makes it challenging to recover the unlensed (source-plane) surface brightness distribution.

We conduct a detailed study to recover the source-plane physical properties of z~2 lensed galaxy using spatially resolved observations from two different multiple images of the lensed target. To deal with PSF’s from two data sets on different multiple images of the galaxy, we employ a forward (Source to Image) approach to merge these independent observations. Using our novel technique, we are able to present a detailed analysis of the source-plane dynamics at scales much better than previously attainable through traditional image inversion methods.

Moreover, our technique is adapted to magnification, thus allowing us to achieve higher resolution in highly magnified regions of the source. We find that this lensed system is highly evident of a minor merger. In my talk, I present this case study of z~2 lensed galaxy and also discuss the applications of our algorithm to study plethora of lensed systems, which will be available through future telescopes like JWST and GMT.

Author(s): Soniya Sharma1, Johan Richard2, Lisa Kewley1, Tianfan Yuan3

Institution(s): 1. Australian National University, 2. CRAL, 3. Swinburne University of Technology

201.07 – Physical Properties of UV-bright Clumps in Star-forming Galaxies at 0.5 ≤ z < 3

Studying giant star-forming clumps in distant galaxies is important to understand galaxy formation and evolution. At present, however, observers and theorists have not reached a consensus on whether the observed "clumps" in distant galaxies are the same phenomenon that is seen in simulations. As a step to establish a benchmark of direct comparisons between observations and theories, we publish a sample of clumps constructed to represent the commonly observed “clumps” in the literature. This sample contains 3193 clumps detected from the rest-frame images of 1270 galaxies at 0.5<z<3.0. The physical properties of clumps (e.g., rest-frame color, stellar mass, star formation rate, age, and dust extinction) are measured by fitting the spectral energy distribution (SED) to synthetic stellar population models. We carefully test the procedures of measuring clump properties, especially the method of subtracting background fluxes from the diffuse component of galaxies. With our fiducial background subtraction, we find a radial clump U-V color variation, where clumps close to galactic centers are redder than those in outskirts. The slope of the color gradient (clump color as a function of their galactocentric distance scaled by the semimajor axis of galaxies) changes with redshift and stellar mass of the host galaxies: at a fixed stellar mass, the slope becomes steeper toward low redshift, and at a fixed redshift, it becomes slightly steeper with stellar mass. Based on our SED fitting, this observed color gradient can be explained by a combination of a
negative age gradient, a negative E(B-V) gradient, and a positive specific star formation rate gradient of the clumps. We also find that the color gradients of clumps are steeper than those of intra-clump regions. Correspondingly, the radial gradients of the derived physical properties of clumps are different from those of the diffuse component or intra-clump regions.

202 – Preparing for JWST Science with the Early Release Science Programs: Distant Galaxies and Cosmic Dawn

“The Director's Discretionary Early Release Science (DD-ERS) program was designed to educate and inform the community regarding JWST’s capabilities, and provide rapid access to substantive, representative datasets to enable full scientific exploitation in Cycle 2 and beyond. The 13 selected programs were announced in November 2017, and the teams have already gotten to work on products to fulfill the mission of the DD-ERS. In this session, team members of DD-ERS programs observing distant galaxies and cosmic dawn will give an overview of their planned observations and the science-enabling products they are working on for the community. We will allow time for discussion with the teams. NOTE: This session will feature an update to the community on the status of JWST.”

Author(s): Yicheng Guo1, Marc Rafelski3, Eric F. Bell4, Avishai Dekel2, Nir Mandelker6, Joel R. Primack3 Institution(s): 1. STScI, 2. The Hebrew University, 3. University of California Santa Cruz, 4. University of Michigan, 5. University of Missouri, 6. Yale University Contributing team(s): CANDELS

202.01 – The Director’s Discretionary Early Release Science Program for JWST

We will introduce the Director's Discretionary Early Release Science (DD-ERS) Program for the James Webb Space Telescope (JWST). These programs will educate and inform the community about JWST's instruments and capabilities, providing open access to early observations, and science-enabling products that the DD-ERS teams produce. During this session, we will provide updates on JWST status, and the 13 selected teams will give an overview of their planned observations and future work.

Author(s): Nancy A. Levenson1, Kenneth Sembach1 Institution(s): 1. Space Telescope Science Institute

202.02 – Dale Kocevski, Colby College

202.03 – TEMPLATES: Targeting Extremely Magnified Panchromatic Lensed Arcs and Their Extended Star formation

TEMPLATES is a JWST Early Release Science program designed to produce high signal-to-noise imaging and IFU spectroscopic data cubes for four gravitationally lensed galaxies at high redshift. The program will spatially resolve the star formation in galaxies across the peak of cosmic star formation in an extinction-robust manner. Lensing magnification pushes JWST to the highest spatial resolutions possible at these redshifts, to map the key spectral diagnostics of star formation and dust extinction: H-alpha, Pa-alpha, and 3.3um PAH emission within individual distant galaxies. Our targets are among the brightest, best-characterized lensed systems known, and include both UV-bright 'normal' galaxies and heavily dust-obscured submillimeter galaxies, at a range of stellar masses and luminosities. I will describe the scientific motivation for this program, detail the targeted galaxies, and describe the planned data products to be delivered to the community in advance of JWST Cycle 2.

Author(s): Justin Spilker3, Jane R. Rigby1, Joaquín D. Vieira2 Institution(s): 1. NASA Goddard, 2. University of Illinois - Urbana / Champaign, 3. University of Texas at Austin Contributing team(s): The TEMPLATES Team

202.04 – Through the Looking GLASS: A JWST exploration of galaxy formation and evolution from cosmic dawn to present day

In the recent years HST observations of blank fields enabled us to detect galaxies as far as z~11. However, very little is known about those galaxies, and they are mostly the most luminous representatives. Clusters of galaxies, when used as cosmic telescopes, can greatly simplify the task of studying and finding normal galaxies at high redshifts. Through the Looking GLASS JWST ERS program is designed to study intrinsically faint magnified galaxies from the epoch of reionization until redshift 1 using an extraordinary lensing cluster Abell 2744. By complimenting deep slitless spectroscopy from NIRISS and high-resolution spectra from the NIRSpec MOS the program will address the origin of the re-ionizing photons and the baryonic cycle of galaxies. NIRCAM imaging will be taken in parallel to the spectroscopy to further aid the exploration of the highest redshift galaxies. In addition, GLASS-ERS data will allow a wealth of other investigations and be of interest to a large section of the astronomical community. I will present the design of the survey as well as the products we plan to provide to the broader community to access this diverse set of JWST data before cycle 2.

Author(s): Marusa Bradac1 Institution(s): 1. University of California, Davis Contributing team(s): JWST ERS Team

203 – Infrared Astrophysics in the SOFIA Era III

This session addresses three topics—(1) The Birth of Planets and Stars, (2) The Path to Life, and (3) Extreme Environments— which are scientific objectives for the Stratospheric Observatory for Infrared Astronomy. SOFIA provides access to celestial far-infrared radiation, from above 99% of the water in the Earth’s atmosphere, following the successes of infrared-optimized telescopes like IRTF and Gemini and space telescopes like Spitzer and Herschel. Far-infrared observations provide synergy with those in the sub-millimeter by ALMA and in the mid-infrared by JWST. This session will present forward-looking prospects in each topic and to tie them to far-infrared capabilities. SOFIA supports numerous PhD theses and ongoing instrument development, both of which will feature in the session.

203.01 – A Three Dimensional Picture of Galactic Center Mass Flows From Kiloparsec to Subparsec Scales

The centers of galaxies host extreme and energetic phenomena, from the amassing of incredibly dense reservoirs of gas to nuclear starbursts producing tens to hundreds of solar masses per year to accreting supermassive black holes launching jets. All of these are found on compact scales from hundreds of parsecs to less than a microparsec. The nearest laboratory for examining these processes is the center of our own Milky Way Galaxy. Although the black hole is not currently active and the star formation rate is relatively low, it is still our best opportunity for detailed insight into the processes that regulate the growth of the central supermassive black hole. By providing access to mid- and far-infrared wavelengths, SOFIA plays a unique role in connecting large and small scales in the Galactic center and studying the cycling of gas through this region. In this talk I will highlight several key open questions and outline the role that SOFIA continues to play in answering them.
203.02 – SOFIA/FORCAST Resolves 30 - 40 μm Extended Emission in Nearby AGN

We present arcsecond-scale observations in the 30 - 40 μm range of seven nearby Seyfert galaxies observed from the Stratospheric Observatory For Infrared Astronomy (SOFIA) using the 31.5 and 37.1 μm filters of the Faint Object infraRed Camera for the SOFIA Telescope (FORCAST). We find extended diffuse emission in the 37.1 μm images in our sample, and isolate this from unresolved torus emission. Using Spitzer/IRS spectra, we determine the dominant mid-infrared (MIR) emission source and attribute it to dust in the narrow line region (NLR) or star formation. We compare the optical NLR and radio jet axes to the extended 37.1 μm emission and find coincident axes for three sources.

Author(s): Lindsay Fuller3, Enrique Lopez-Rodriguez2, Christopher C. Packham3, Kohei Ichikawa1, Aditya Togi3
Institution(s): 1. Columbia University, 2. SOFIA Science Center, NASA Ames Research Center, 3. University of Texas at San Antonio

203.03 – Shocked molecular gas and the origin of cosmic rays

When massive stars reach the end of their ability to remain stable with core nuclear fusion, they explode in supernovae that drive powerful shocks into their surroundings. Because massive stars form in and remain close to molecular clouds they often drive shocks into dense gas, which is now believed to be the origin of a significant fraction of galactic cosmic rays. The nature of the supernova-molecular cloud interaction is not well understood, though observations are gradually elucidating their nature. The range of interstellar densities, and the inclusion of circumstellar matter from the late-phase mass-loss of the stars before their explosions, leads to a wide range of possible appearances and outcomes. In particular, it is not even clear what speed or physical type of shocks are present: are they dense, magnetically-mediated shocks where H$_2$ is not dissociated, or are they faster shocks that dissociate molecules and destroy some of the grains? SOFIA is observing some of the most significant (in terms of cosmic ray production potential and infrared energy output) supernova-molecular cloud interactions for measurement of the line widths of key molecular shocks tracers: H$_2$, [OI], and CO. The presence of gas at speeds 100 km/s or greater would indicate dissociative shocks, while speeds 30 km/s and slower retain most molecules. The shock velocity is a key ingredient in modeling the interaction between supernovae and molecular clouds including the potential for formation of cosmic rays.

Author(s): William Reach3, Antoine Gudorfi1, Matthew Richter2
Institution(s): 1. CNRS, 2. UC Davis, 3. USRA

204 – LAD: Bridging Laboratory & Astrophysics: Plasma Processes in the X-ray and Beyond

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on plasma properties in the sun, the laboratory, and as probe by X-ray observations.

204.01 – LAD Dissertation Prize: Laboratory Identification of Magnetohydrodynamic Eruption Criteria in the Solar Corona

Ideal magnetohydrodynamic instabilities such as the kink and torus instabilities are believed to play an important role in driving storage-and-release eruptions in the solar corona. These instabilities act on long-lived,arching magnetic flux ropes that are line-tied to the solar surface. In spite of numerous observational and computational studies, the conditions under which these instabilities produce an eruption remain a subject of intense debate. In this paper, we use a line-tied, arched flux rope experiment to systematically study storage-and-release eruption mechanisms in the laboratory. In situ thin magnetic probes facilitate the study of both the equilibrium and the stability of these laboratory flux ropes. In particular, they permit the direct measurement of magnetic (J*B) forces, both in equilibrium and during dynamic events. Regarding stability and eruptions, two major results are reported: First, a new stability regime is identified where torus-unstable flux ropes fail to erupt. In this ‘failed torus’ regime, the flux rope is torus-unstable but kink-stable. Under these conditions, a dynamic toroidal field tension force surges in magnitude and prevents the flux rope from erupting. This dynamic tension force, which is missing from existing eruption models, is generated by magnetic self-organization events within the line-tied flux rope. Second, a clear torus instability threshold is observed in the kink-unstable regime. This latter result, which is consistent with existing theoretical and numerical results, verifies the key role of the torus instability in driving flux rope eruptions in the solar corona.

Author(s): Elisabeth A. Mills1
Institution(s): 1. Boston University

205.04 – The First Non-Dispersive High-Resolution Spectroscopy of an X-ray-bright Galaxy Cluster

The Hitomi X-ray Observatory was equipped with the Soft X-ray Spectrometer (SXS), an X-ray microcalorimeter that achieved an energy resolution of 5 eV (@0.5-10 keV) for extended objects. This offered an unprecedented benchmark of atomic modeling and database for hot collisional plasmas, revealing both successes and challenges in the current atomic codes that are widely used by the X-ray astronomy community. I will review the Hitomi observations of the brightest part of the Perseus Cluster, whose X-ray spectrum is dominated by thermal emission from the intra-cluster medium (ICM). The SXS successfully measured the turbulent velocities and metal abundances of the ICM, which radically altered our understanding of the dynamics and chemical enrichment in this object. At the same time, the high-resolution X-ray data led to significant improvement in the atomic models, such as AtomDB and SPEX – I will briefly overview how this improvement was made. Nevertheless, there are still significant discrepancies among the public atomic models, causing systematic uncertainties in measurements of the temperature, abundance, and degree of the resonance scattering. Requirements for future improvements will be summarized in this context.

Author(s): Hiroya Yamaguchi1
Institution(s): 1. NASA/GSFC
Contributing team(s): Hitomi Collaboration

204.03 – Spectroscopy of X-ray Photoionized Plasmas in the Laboratory

The physical processes operating in astrophysical plasmas --- heating, cooling, ionization, recombination, level population kinetics, and radiation transport --- are all accessible to...
205 – Stellar Abundances in Dwarf Galaxies III: Dwarf Galaxy Insights into Neutron-capture Nucleosynthesis

205.04 – Implications of Barium Abundances for the Chemical Enrichment of Dwarf Galaxies

There are many candidate sites of the r-process: core-collapse supernovae (including rare magnetorotational core-collapse supernovae), neutron star mergers (NSMs), and neutron star/black hole mergers. The chemical enrichment of galaxies—specifically dwarf galaxies—helps distinguish between these sources based on the continual build-up of r-process elements. The existence of several nearby dwarf galaxies allows us to measure robust chemical abundances for galaxies with different star formation histories. Dwarf galaxies are especially useful because simple chemical evolution models can be used to determine the sources of r-process material. We have measured the r-process element barium with Keck/DEIMOS medium-resolution spectroscopy. We will present the largest sample of barium abundances (more than 200 stars) in dwarf galaxies ever assembled. We measure [Ba/Fe] as a function of [Fe/H] in this sample and compare with existing [alpha/Fe] measurements. We have found that a large contribution of barium needs to occur at timescales similar to Type Ia supernovae in order to recreate our observed abundances, namely the flat or slightly rising trend of [Ba/Fe] vs. [Fe/H]. We conclude that neutron star mergers are the main contribution of r-process enrichment in dwarf galaxies.

Author(s): Gina Duggan1, Evan N Kirby4
Institution(s): 1. California Institute of Technology

205.05 – Modeling Neutron stars as r-process sources in Ultra Faint Dwarf galaxies

To explain the high observed abundances of r-process elements in local ultrafaint dwarf (UFD) galaxies, we perform cosmological zoom simulations that include r-process production from neutron star mergers (NSMs). We model star formation stochastically and simulate two different haloes with total masses \( \approx 108 \, \text{M}_\odot \) at \( z = 6 \). We find that the metal distribution of [Eu/H] versus [Fe/H] is relatively insensitive to the energy by which the r-process material is ejected into the interstellar medium, but strongly sensitive to the environment in which the NSM event occurs. In one halo, the NSM event takes place at the centre of the stellar distribution, leading to high levels of r-process enrichment such as seen in a local UFD, Reticulum II (Ret II). In a second halo, the NSM event takes place outside of the densest part of the galaxy, leading to a more extended r-process distribution. The subsequent star formation occurs in an interstellar medium with shallow levels of r-process enrichment that results in stars with low levels of [Eu/H] compared to Ret II stars even when the maximum possible r-process mass is assumed to be ejected. This suggests that the natal kicks of neutron stars may also play an important role in determining the r-process abundances in UFD galaxies, an topic that warrants further theoretical investigation.

Author(s): Duane A. Liedahl1, Guillaume Loise14, James E Bailey4, Taisuke Nagayama4, Stephanie B. Hansen4, Gregory Rochau4, Christopher J Fontes2, Roberto Mancini5, Timothy R Kallman3
Institution(s): 1. LLNL, 2. Los Alamos National Laboratory, 3. NASA/GSFC, 4. Sandia National Laboratory, 5. University of Nevada Reno

observation in the laboratory. What distinguishes X-ray photoionized plasmas from the more common case of high-temperature collisionally-ionized plasmas is the elevated level of importance of the radiation/matter interaction. The advent of laboratory facilities with the capability to generate high-powered X-ray sources has provided the means by which to study this interaction, which is also fundamental to active galactic nuclei and other accretion-powered objects. We discuss recent and ongoing experiments, with an emphasis on X-ray spectroscopic measurements of silicon plasmas obtained at the Sandia Z Pulsed Power Facility.
206 – Indigenous Knowledge in 21st Century Science

As the professional astronomy community endeavors to make its community more equitable and inclusive, it is becoming increasingly evident that there is an interconnection between astronomical scientific and educational activities and Indigenous Knowledge (IK). From the historical understanding of the cosmos and unique perspectives of time and space originally perceived by Indigenous peoples, to conflicts over the expansion of telescope facilities onto sacred tribal or Indigenous lands, it has become more important than ever to respect, dialog, and partner with Indigenous people and communities in our scientific endeavors. Our proposed session aims to give an introduction to and explore IK and sky traditions through a panel of astronomers expert in Navajo, Maya/Inka and Hawaiian traditions. Through these presentations and a follow-on discussion session, we aim to examine how the richness of astronomical traditions from various Indigenous cultures can be juxtaposed with western astronomy in a way that enhances science education and research while honoring the integrity and authenticity of the perspectives we explore. Improved understanding of Indigenous ways of knowing, through traditional IK concepts of “Space and Place” and IK values of collaboration, deep listening, and sustainability, are relevant for both improved communication of astronomical research with the broader community and better understanding of community tensions over proposed astronomical facilities. Only by understanding and embracing the deep historical, cultural and traditional language base of Indigenous science can we create a scientific enterprise that is more sustainable, inclusive and respectful.

207 – Plenary Talk: The Dynamics of the Local Group in the Era of Precision Astrometry, Gurtina Besla (University of Arizona)

207.01 – The Dynamics of the Local Group in the Era of Precision Astrometry

Our understanding of the dynamics of our Local Group of galaxies has changed dramatically over the past few years owing to significant advancements in astrometry and our theoretical understanding of galaxy structure. New surveys now enable us to map the 3D structure of our Milky Way and the dynamics of tracers of its dark matter distribution, like globular clusters, satellite galaxies and streams, with unprecedented precision. Some results have met with controversy, challenging preconceived notions of the orbital dynamics of key components of the Local Group. I will provide an overview of this evolving picture of our Local Group and outline how we can test the cold dark matter paradigm in the era of Gaia, LSST and JWST.

Author(s): Gurtina Besla1, Nicolas Garavito-Camargo1, Ekta Patel1
Institution(s): 1. University of Arizona

209 – College-Level Astronomy Education: Research & Resources

209.01 – Astrobits as a Pedagogical Tool in Classrooms

Astrobits is a graduate-student organization that publishes an online astrophysical literature blog (astrobits.org), and has published brief and accessible summaries of more than 1600 articles from the astrophysical literature since its founding in 2010. Our graduate-student generated content is widely being utilized as a pedagogical tool to bring current research into the classroom of higher education. We aim to study the effectiveness of Astrobits in teaching of current research, via the AAS Education & Professional Development Mini-Grant funded in Fall 2017. This talk gives an overview of the functioning of Astrobits, our past pedagogical initiatives, as well as a brief description of the grant proposal. We describe the workings of our teaching workshop at the 231st AAS Meeting in January 2018, as well as a 10-educator focus group that has been assembled to conduct a post-workshop follow-up that serves as a dataset for our research study. We present here a brief analysis of the workshop, the focus group and preliminary inferences.

Author(s): Gourav Khullar3, Benny Tsz Ho Tsang4, Nathan Sanders2, Susanna Kohler1, Nora Shipp3
Institution(s): 1. AAS, 2. Astrobits Collaboration, 3. The University of Chicago, 4. The University of Texas at Austin
Contributing team(s): Astrobits Collaboration

209.02 – Research on a Unique Instructional Framework for Elevating Students’ Quantitative Problem Solving Abilities

We present an instructional framework that allowed a first time physics instructor to improve students quantitative problem solving abilities by more than a letter grade over what was achieved by students in an experienced instructor’s course. This instructional framework uses a Think-Pair-Share approach to foster collaborative quantitative problem solving during the lecture portion of a large enrollment introductory calculus-based mechanics course. Through the development of carefully crafted and sequenced TPS questions, we engage students in rich discussions on key problem solving issues that we typically only hear about when a student comes for help during office hours. Current work in the sophomore E&M course illustrates that this framework is generalizable to classes beyond the introductory level and for topics beyond mechanics.

Author(s): Allyson Bieryla1, Wanda Diaz Merced2, Daniel Davis1
Institution(s): 1. Harvard University, 2. South African Astronomical Observatory

209.04 – Evaluation of an Interactive Undergraduate Cosmology Curriculum

The Big Ideas in Cosmology is an immersive set of web-based learning modules that integrates text, figures, and visualizations with short and long interactive tasks as well as labs that allow...
students to manipulate and analyze real cosmological data. This enables the transformation of general education astronomy and cosmology classes from primarily lecture and book-based courses to a format that builds important STEM skills, while engaging those outside the field with modern discoveries and a more realistic sense of practices and tools used by professional astronomers. Over two semesters, we field-tested the curriculum in general education cosmology classes at a state university in California [N ~ 80]. We administered pre- and post-instruction multiple-choice and open-ended content surveys as well as the CLASS, to gauge the effectiveness of the course and modules. Questions addressed included the structure, composition, and evolution of the universe, including students’ reasoning and “how we know.”

Module development and evaluation was supported by NASA ROSES E/PO Grant #NNX10AC89G, the Illinois Space Grant Consortium, the Fermi E/PO program, Sonoma State University’s Space Science Education and Public Outreach Group, and San Francisco State University. The modules are published by Great River Learning/Kendall-Hunt.

Author(s): Aaron White2, Kimberly A. Coble2, Dominique Martin1, Patrycia Hayes3, Tom Targett3, Lynn R. Cominsky3
Institution(s): 1. Chicago State University, 2. San Francisco State University

209.05 – GEAS Spectroscopy Tools for Authentic Research Investigations in the Classroom
Spectroscopy is one of the most powerful tools that astronomers use to study the universe. However relatively few resources are available that enable undergraduates to explore astronomical spectra interactively. We present web-based applications which enable the transformation of general education astronomy and cosmology classes from primarily lecture and book-based courses to a format that builds important STEM skills, while engaging those outside the field with modern discoveries and a more realistic sense of practices and tools used by professional astronomers.

Author(s): Travis A. Rector2, Nicole P. Vogt1
Institution(s): 1. New Mexico State University, 2. Univ. of Alaska Anchorage

210 – Preparing for JWST Science with the Early Release Science Programs: Nearby and Resolved Galaxies
“The Director’s Discretionary Early Release Science (DD-ERS) program was designed to educate and inform the community regarding JWST’s capabilities, and provide rapid access to substantive, representative datasets to enable full scientific exploitation in Cycle 2 and beyond. The 13 selected programs were announced in November 2017, and the teams have already gotten to work on products to fulfill the mission of the DD-ERS. In this session, team members of DD-ERS programs observing “nearby” galaxies will give an overview of their planned observations and the science-enabling products they are working on for the community. We will allow time for discussion with the teams.

Author(s): Karoline Gilbert1, Daniel Weisz2
Institution(s): 1. Space Telescope Science Institute, 2. University of California, Berkeley
Contributing team(s): The Resolved Stellar Populations ERS Program Team

210.04 – A JWST Study of the Starburst-AGN Connection in Merging Luminous Infrared Galaxies
Galaxies evolve through a combination of secular processes, such as cold gas accretion, and nonsecular processes, such as galactic mergers, which can trigger massive starbursts and powerful AGN. JWST will transform our understanding of galactic evolution, providing a detailed look at the physics of star formation and black hole growth in nearby merging galaxies. Using NIRSPEC, NIRCAM and MIRI, our ERS program will provide a rich dataset for understanding the dynamics and energetics of the ISM on scales of 50-100pc in the nuclei of local Luminous Infrared Galaxies (LIRGs). Our four targets (NGC 5256, NGC 7469, VV 114 and IRAS 08572+3915) cover a range of starburst-to-AGN power, merger stage, and IR spectral properties. I will summarize our ERS program science goals for unraveling the complex galactic ecosystems in active and starburst galaxies at low redshifts and our plans for science-enabling data products.

Author(s): Lee Armus1
Institution(s): 1. Caltech
Contributing team(s): The GOALS ERS Team

211 – Low Radio Frequency Observations from Space: Low Radio Frequency Heliophysics from Space
Many spacecraft have observed solar and planetary radio emissions at frequencies below Earth’s ionospheric cutoff (≤15 MHz); however, none of those missions have been designed to image radio bursts at such long wavelengths (>30 m). This session will present the background and simulations indicating why such imaging observations would be valuable, including a CubeSat mission proposal to perform such imaging observations, a radio receiver instrument that will be located in the lunar environment, and the design of a low-frequency radio observatory for the lunar surface.

211.01 – Overview of Solar Radio Bursts and their Sources
Properties of radio bursts emitted by the Sun at frequencies below tens of MHz are reviewed. In this frequency range, the most prominent radio emissions are those of solar type II, complex type III and solar type IV radio bursts, excited probably by the energetic electron populations accelerated in completely different environments: (1) type II bursts are due to non-relativistic electrons accelerated by the CME-driven interplanetary shocks, (2) complex type III bursts are due to near-relativistic electrons accelerated either by the flare reconnection process or by the SEP shocks, and (3) type IV bursts are due to relativistic electrons, trapped in the post-eruption arcades behind CMEs; these relativistic electrons probably are accelerated by the continued reconnection processes occurring behind the CME. These radio bursts, which can serve as the natural plasma probes traversing the heliosphere by providing information about various crucial space plasma parameters, are also an ideal instrument for investigating acceleration mechanisms responsible for the high energy particles. The rich collection of valuable high quality radio and high time resolution in situ wave data from the WAVES experiments of the STEREO A, STEREO B and WIND spacecraft has provided an unique opportunity to study these different radio phenomena and understand the complex physics behind their excitation. We have developed Monte Carlo simulation techniques to estimate the propagation effects on the observed characteristics of these low frequency radio burst. We will present some of the new results and describe how one can use these radio burst observations for space weather studies. We will also describe some of the non-linear plasma processes detected in the source regions of both solar type III and type II radio bursts. The analysis and simulation techniques used in these studies will be of immense use for future space based radio observations.

Author(s): Thejappa Golla1, Robert J MacDowall1
Institution(s): 1. NASA, Goddard Space Flight Center, 2. Univ. of Maryland

211.02 – Sun Radio Interferometer Space Experiment (SunRISE)
The Sun Radio Interferometer Space Experiment (SunRISE) is a NASA Heliophysics Explorer Mission of Opportunity currently in Phase A. SunRISE is a constellation of spacecraft flying in a 10-km diameter formation and operating as the first imaging radio interferometer in space. The purpose of SunRISE is to reveal critical aspects of solar energetic particle (SEP) acceleration at coronal mass ejections (CMEs) and transport into space by making the first spatially resolved observations of coherent Type II and III radio bursts produced by electrons accelerated at CMEs or released from flares. SunRISE will focus on solar Decametric-Hectometric (DH, 0.1 < f < 15 MHz) radio bursts that always are detected from space before major SEP events, but cannot be seen on Earth due to ionospheric absorption. This talk will describe SunRISE objectives and implementation. Presented on behalf of the entire SunRISE team.

Author(s): Justin C Kasper1
Institution(s): 1. University of Michigan
Contributing team(s): SunRISE Team

211.03 – Radio Astronomy on and Around the Moon
The exploration of remote places on other planets has now become a major goal in current space flight scenarios. On the other hand, astronomers have always sought the most remote and isolated sites to place their observatories and to make their most precise and most breath-taking discoveries. Especially for radio astronomy, lunar exploration offers a complete new window to the universe. The polar region and the far-side of the moon are acknowledged as unique locations for a low-frequency radio telescope providing scientific data at wavelengths that cannot be obtained from the Earth nor from single satellites. Scientific areas to be covered range from radio surveys, to solar-system studies, exo-planet detection, and astroparticle physics. The key science area, however, is the detection and measurement of cosmological hydrogen emission from the still unexplored dark ages of the universe. Developing a lunar radio facility can happen in steps and may involve small satellites, rover-based radio antennas, of free-flying constellations around the moon. A first such step could be the Netherlands-Chinese Long Wavelength Explorer (NCLE), which is supposed to be launched in 2018 as part of the ChangE’4 mission to the moon-earth L2 point.

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Contributing team(s): Marc Klein Wolt Radboud Universiteit Nijmegen, Jinsong PingNational Astronomical Observatories Chinese Academy of Sciences, Linjie Chen National Astronomical Observatories CAS

211.04 – Low-frequency Radio Observatory on the Lunar Surface (LROLS)
A radio observatory on the lunar surface will provide the capability to image solar radio bursts and other sources. Radio burst imaging will improve understanding of radio burst mechanisms, particle acceleration, and space weather. Low-frequency observations (less than ~20 MHz) must be made from space, because lower frequencies are blocked by Earth’s ionosphere. Solar radio observations do not mandate an observatory on the far-side of the Moon, although such a location would permit study of less intense solar bursts because the Moon occults the terrestrial radio frequency interference. The components of the lunar radio observatory array are: the antenna system consisting of 10 – 100 antennas distributed over a square kilometer or more; the system to transfer the radio signals from the antennas to the central processing unit; electronics to digitize the signals and possibly to calculate correlations; storage for the data until it is down-linked to Earth. Such transmission requires amplification and a high-gain antenna system or possibly laser comm. For observatories on the lunar far-side a satellite or other intermediate transfer system is required to direct the signal to Earth. On the ground, the aperture synthesis analysis is completed to display the radio image as a function of time. Other requirements for lunar surface systems include the power supply, utilizing solar arrays with batteries to maintain the system at adequate thermal levels during the lunar night. An alternative would be a radioisotope thermoelectric generator requiring less mass. The individual antennas might be designed with their own solar arrays and electronics to transmit data to the central processing unit, but surviving lunar night would be a challenge. Harnesses for power and data transfer from the central processing unit to the antennas are an alternative, but a harness-based system complicates deployment. The concept of placing the antennas and harnesses on rolls of polyimide and rolling them out may be a solution for solar radio observations, but it probably does not provide a sufficiently-uniform beam for other science targets.

Author(s): Robert MacDowall1
Institution(s): 1. NASA/GSFC
Contributing team(s): Network for Exploration and Space Science (NESS)

211.05 – Numerical simulations of particle acceleration and low frequency radio emission in stellar environments
Due to their favorable atmospheric window radio waves are a useful tool for ground-based observations of astrophysical systems throughout a plethora of scales, from cosmological down to planetary ones. A wide range of physical mechanisms, from thermal processes to eruptive events linked to magnetic reconnection, can generate emission in radio frequencies. Radio waves have the distinct characteristic that they follow curved paths as they propagate in stratified environments, such as the solar corona, due to their dependence on the refractive index. Low frequency radio rays in particular are affected the most by refraction.

Solar radio observations are of particular importance, since it is possible to spatially resolve the Sun and its corona and gain insights on highly dynamic and complex radio-emitting phenomena. The multi-scale problem of particle acceleration and energy partition between CMEs, flares and SEPs requires both MHD and kinetic considerations to account for the emission and mass propagation through the interplanetary space.

Radio observations can play a significant role in the rapidly developing area of exoplanetary research and provide insights on the stellar environments of those systems. Even though a large number of flares has been observed for different stellar types, nevertheless there is a lack of stellar CME observations. Currently, the most promising method to incontrovertibly observe stellar CMEs is through Type II radio bursts. Low frequency radio emission can also be produced by the interaction of a magnetized planet with the stellar wind of the host star.

The above mentioned characteristics of radio-waves make their integration into numerical simulations imperative for capturing and disentangling the complex radio emitting processes along the actual radio paths and provide the observers with detection limits for future Earth- and space-based missions. Radio synthetic imaging tools incorporated in realistic computational codes are already available for solar radio-emitting processes with different physical and observational characteristics.

**212 – LAD: Bridging Laboratory & Astrophysics: Disks and Circumstellar Outflows in the JWST Era**

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on disk modeling in the near infrared in the interplay of surface interactions and molecular spectroscopy.

**212.01 – The physical and chemical evolution of disks during planet formation**

Protoplanetary disks evolve and disperse rapidly during the early stages of star and planet formation. While disks initially inherit a full complement of interstellar cloud material that is mainly accreted on to the central star, their gas and dust components appear to evolve along distinct pathways. Dust accumulates to form rocky planets, whereas only a small fraction of the available gas may be incorporated into gas giants in a typical exoplanetary system. However, the radial distribution of gas and its chemistry are expected to impact the architecture and composition of formed planets. Recent ALMA results have underscored the importance of ices and grain surface chemistry in disks, and their significance for planet formation. I will describe disk models that aim to probe the physical and chemical processes in the disk at various stages of evolution, and specifically discuss diagnostics of conditions in the innermost regions of disks which will become accessible for the first time with the launch of JWST. Current theoretical modeling is however hindered by many uncertainties in input parameters and poorly known chemical and physical processes. I will highlight some gaps in our current understanding, and discuss how laboratory astrophysics can help in preparing for the JWST era and aid in the interpretation of future line and continuum emission studies.

**Author(s): Uma Gorti**
**Institution(s):** 1. NASA Ames Research Center

**212.02 – Quantifying atom addition reactions on amorphous solid water: a review of recent laboratory advances**

Complex organic molecules found in space are mostly formed on and in the ice mantle covering interstellar dust grains. In clouds where ionizing irradiation is insignificant, chemical reactions on the ice mantle are dominated by thermal processes. Modeling of grain surface chemistry requires detailed information from the laboratory, including sticking coefficients, binding energies, diffusion energy barriers, mechanism of reaction, and chemical desorption rates. In this talk, recent laboratory advances in obtaining these information would be reviewed. Specifically, this talk will focus on the efforts in our group in: 1) Determining the mechanism of atomic hydrogen addition reactions on amorphous solid water (ASW); 2) Measuring the chemical desorption coefficient of H+O3−→O2+OH using the time-resolved scattering technique; and 3) Measuring the diffusion energy barrier of volatile molecules on ASW. Further laboratory studies will be suggested.

This research was supported by NSF Astronomy & Astrophysics Research Grant #1615897.

**Author(s): Jiao He**
**Institution(s):** 1. Syracuse University

**212.03 – Spectroscopic Data for Characterizing the Atmospheres of Exoplanets and Assigning Astronomical Spectra**

In this talk I will discuss laboratory and computational efforts to provide detailed line list data for use in characterizing the atmospheres of planets, exoplanets, and other astrophysical objects such as dwarf stars. The discussion will cover significant efforts on stable molecules routinely found in atmospheres such as CO2, NH3, H2O, and SO2. In addition, there will be some discussion towards efforts to provide more limited line lists or simulated spectra for molecules that might be present in trace amounts, but would be very significant if identified, such as possible biosignatures. How these efforts may provide insight into astronomical observations, especially with the upcoming James Webb Space Telescope, will also be discussed.

**Author(s): Timothy J. Lee**
**Institution(s):** 1. Ames Research Center - NASA

**213 – Stellar Abundances in Dwarf Galaxies IV: NLTE and Advanced Abundance Measurements**

**213.01 – Heavy elements in ultra-faint dwarf galaxies**

Most ultra-faint dwarf galaxies contain relatively few heavy elements, but at least one, Reticulum II, contains orders of magnitude more than any other known ultra-faint dwarf galaxy. In Reticulum II, the heavy element nucleosynthesis was clearly dominated by the r-process. I will describe attempts to identify the nucleosynthesis process(es) responsible for the low levels of heavy elements in other ultra-faint dwarf galaxies. I will also
discuss our group’s recent Magellan/M2FS observations of heavy elements in Reticulum II as a proof of concept for how to efficiently identify other r-process-rich galaxies in the future.

**Author(s):** Ian Roederer

**Institution(s):** 1. University of Michigan

### 213.02 – Towards new generation spectroscopic models of cool stars

Abstract: Spectroscopy is a unique tool to determine the physical parameters of stars. Knowledge of stellar chemical abundances, masses, and ages is the key to understanding the evolution of their host populations. I will focus on the current outstanding problems in spectroscopy of cool stars, which are the most useful objects in studies of our local Galactic neighborhood but also very distant systems, like faint dwarf Spheroidal galaxies. Among the most debated issues is to what extent can we trust the techniques, which rely on the classical assumptions of local thermodynamic equilibrium and hydrostatic balance. I will summarise the ongoing efforts to improve the models of cool stars, with the emphasis on NLTE and 3D modelling. I will then discuss how these exciting observations impact our knowledge of abundances in the Milky Way and in dSph systems, and present outlook for the future studies.

**Author(s):** Maria Bergemann

**Institution(s):** 1. Max Planck Institute for Astronomy

### 213.03 – Early chemical enrichment of the Galactic dwarf satellites from a homogeneous and NLTE abundance analysis

We review recent abundance results for very metal-poor (VMP, \(-4 \leq [\text{Fe/H}] \leq -2\)) stars in seven dwarf spheroidal galaxies (dSphs) and in the Milky Way (MW) halo comparison sample that were obtained based on high-resolution spectroscopic datasets, homogeneous and accurate atmospheric parameters, and the non-local thermodynamic equilibrium (NLTE) line formation for 10 chemical species. A remarkable gain of using such an approach is the reduction, compared to a simple compilation of the literature data, of the spread in abundance ratios at given metallicity within each galaxy and from one to the other. We show that all massive galaxies in our sample, that is, the MW halo and the classical dSphs Sculptor, Ursa Minor, Sextans, and Fornax, reveal a similar plateau at [\(\alpha/\text{Fe}\)] \sim 0.3 for each of the \(\alpha\)-process elements: Mg, Ca, and Ti. We put on a firm ground the evidence for a decline in \(\alpha/\text{Fe}\) with increasing metallicity in the Boötes I ultra-faint dwarf galaxy (UFD), that is most probably due to the ejecta of type Ia supernovae. In our classical dSphs, we observe the dichotomy in the [Sr/Ba] versus [Ba/H] diagram, similarly to the MW halo, calling for different nucleosynthesis channels for Sr at the earliest evolution stages of these galaxies. Our three UFDs, that is Boötes I, UMa II, and Leo IV, are depleted in Sr and Ba relative to Fe and Mg, with very similar ratios of [Sr/Mg] \sim -1.3 and [Ba/Mg] \sim -1 on the entire range of their Mg abundances. The subsolar Sr/Ba ratios of Boötes I and UMa II indicate a common r-process origin of their neutron-capture elements. For Na/Fe, Na/Mg, and Al/Mg, the MW halo and all dSphs reveal indistinguishable trends with metallicity, suggesting that the processes of Na and Al synthesis are identical in all systems, independent of their mass. Sculptor remains the classical dSph, in which the evidence for inhomogeneous mixing in the early evolution stage, at [\(\text{Fe/H}\)] < -2, is the strongest.

**Author(s):** Lyudmila Mashonkina, Pascale Jablonka, Tatjana Sitnova, Yuri Pakhomov, Pierre North

**Institution(s):** 1. Institute of Astronomy, RAS, 2. Laboratoire d’Astrophysique, Ecole Polytechnique F, ed’ ere de Lausanne (EPFL)

### 213.04 – Atmospheric parameters and magnesium and calcium NLTE abundances for a sample of 16 ultra metal-poor stars

The most metal-poor stars provide important observational clues to the astrophysical objects that enriched the primordial gas with heavy elements. Accurate atmospheric parameters are a prerequisite of determination of accurate abundances. We present atmospheric parameters and abundances of calcium and magnesium for a sample of 16 ultra-metal poor (UMP) stars. In spectra of UMP stars, iron is represented only by lines of Fe I, while calcium is represented with lines of Ca I and Ca II, which can be used for determination/checking of effective temperature and surface gravity. Accurate calculations of synthetic spectra of UMP stars require non-local thermodynamic equilibrium (NLTE) treatment of line formation, since deviations from LTE grow with metallicity decreasing. The method of atmospheric parameter determination is based on NLTE analysis of lines of Ca I and Ca II, multi-band photometry, and isochrones. The method was tested in advance with the ultra metal-poor giant CD-38 245, where, in addition, trigonometric parallax measurements from Gaia DR1 and lines of Fe I and Fe II are available. Using photometric Teff = 4900 K and distance based log g = 2.0 for CD-38 245, we derived consistent within error bars NLTE abundances from Fe I and Fe II and Ca I and Ca II, while LTE leads to a discrepancy of 0.6 dex between Ca I and Ca II. We determined NLTE and LTE abundances of magnesium and calcium in 16 stars of the sample. For the majority of stars, as expected, [Ca/Mg] NLTE abundance ratios are close to 0, while LTE leads to systematically higher [Ca/Mg], by up to 0.3 dex, and larger spread of [Ca/Mg] for different stars. Three stars of our sample are strongly enhanced in magnesium, with [Mg/Ca] of 1.3 dex. It is worth noting that, for these three stars, we got very similar [Mg/Ca] of 1.30, 1.45, and 1.29, in contrast to the data from the literature, where, for the same stars, [Mg/Ca] vary from 0.7 to 1.4. Very similar [Mg/Ca] abundance ratios of these stars argue that their abundances originate from a similar nucleosynthetic event.

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**Institution(s):** 1. Institute of Astronomy, Russian Academy of Sciences, 2. Kavli Institute for Astrophysics and Space Research

### 214 – Astrophysics Archives in the 2020s

The Astrophysics Archives are a vital resource for research with NASA’s astrophysics missions. Consistent support for these archives has provided significant results over the past 25+ years. NASA has found that well-supported archives can provide a doubling of the number of refereed papers from the mission. As data analysis and data mining techniques have become more sophisticated, these archives are continuing to evolve to meet the needs of our users. As we approach the 2020 Decadal Survey, the NASA Astrophysics Archives and Data Centers are studying the trajectory of data analysis, especially the needs for server-side analysis, machine learning, and multi-wavelength, multi-archive research. At this special session, we review the major challenges facing the Archives as we enter the era of JWST, large-area multi-wavelength surveys, enormous data sets, and data science. We will discuss the strong connection between NASA and ground-based astronomy — including the need for interoperability -- and the similarity of the challenges faced by the various communities. The archives and their communities will discuss the ongoing progress to meet the challenges of the future.

#### 214.01 – NASA/IPAC Infrared Science Archive (IRSA) in the 2020s.

I will discuss challenges faced by IRSA in the next decade due to changes in our user base: the dissolution of wavelength boundaries among astronomers, and the education of astronomers as data scientists. While the fraction of astronomers who use infrared data has increased drastically in the era of Spitzer, Herschel, and WISE, most people who do science with those data sets don’t use infrared data exclusively or identify as “Infrared astronomers”. Our archive, and others, need to be responsive to the needs of an increasingly multiwavelength
community, and those exploring time domain astronomy. That means making the archives interlink seamlessly, while preserving expert knowledge so that data don’t get misused. As astronomical data sets grow in volume, users will increasingly expect server side resources, including both storage and analysis resources. These expectations come with a host of ramifications, from cost to security. Our archives must be built to satisfy the needs of both the power user and the beginning astronomer. I will discuss how IRSA plans to meet the evolving needs of our user community.

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Institution(s): 1. Caltech/IPAC
Contributing team(s): IRSA Team

214.02 – Archiving of interferometric radio and mm/submm data at the National Radio Astronomy Observatory
Modern radio interferometers such as ALMA and the VLA are capable of producing ~1TB/day of data for processing into image products of comparable size. Besides the sheer volume of data, the products themselves can be complicated and are sometimes hard to map into standard astronomical archive metadata. We also face similar issues to those faced by archives at other wavelengths, namely the role of archives as the basis of reprocessing platforms and facilities, and the validation and ingestion of user-derived products. In this talk I shall discuss the plans of NRAO in these areas over the next decade.

Author(s): Mark Lacy1
Institution(s): 1. NRAO

214.03 – An Expertise Engine: MAST in the 2020s
The original Hubble Space Telescope archive showed how encapsulating expertise in science-ready data products could accelerate the pace of scientific advancement, and enable extremely productive archival research. In the 2000s, MAST and the Hubble Legacy Archive showed how taking these products to the next level further democratized astronomy, with archival science overtaking PI science as the dominant output of MAST missions. We argue that these data products fundamentally act as a vector for expertise, allowing novice users access to the detailed and advanced techniques of experts. In the 2020s we will see an explosion of data volume, data precision, and data complexity which will demand an even more powerful and sophisticated expertise engine. We’ll discuss how MAST plans to rise to meet that challenge.

Author(s): Joshua Eli Goldston Peek1, Arfon M Smith1, Ivelina G. Momcheva1
Institution(s): 1. Space Telescope Science Institute

214.04 – Data-Oriented Astrophysics at NOAO: The Science Archive & The Data Lab
As we keep progressing into an era of increasingly large astronomy datasets, NOAO’s data-oriented mission is growing in prominence. The NOAO Science Archive, which captures and processes the pixel data from mountaintops in Chile and Arizona, now contains holdings at petabyte scales. Working at the intersection of astronomy and data science, the main goal of the NOAO Data Lab is to provide users with a suite of tools to work close to this data, the catalogs derived from them, as well as externally provided datasets, and thus optimize the scientific productivity of the astronomy community. These tools and services include databases, query tools, virtual storage space, workflows through our Jupyter Notebook server, and scripted analysis. We currently host datasets from NOAO facilities such as the Dark Energy Survey (DES), the DESI imaging Legacy Surveys (LS), the Dark Energy Camera Plate Survey (DECaPS), and the nearly all-sky NOAO Source Catalog (NSC). We are further preparing for large spectroscopy datasets such as DESI. After a brief overview of the Science Archive, the Data Lab and datasets, I will briefly showcase scientific applications showing use of our data holdings. Lastly, I will describe our vision for future developments as we tackle the next technical and scientific challenges.

Author(s): Stephanie Juneau1
Institution(s): 1. NOAO
Contributing team(s): NOAO Data Lab, NOAO Science Archive

214.05 – Facilitating Science Discoveries from NED Today and in the 2020s
I will review recent developments, work in progress, and major challenges that lie ahead as we enhance the capabilities of the NASA/IPAC Extragalactic Database (NED) to facilitate and accelerate multi-wavelength research on objects beyond our Milky Way galaxy. The recent fusion of data for over 470 million sources from the 2MASS Point Source Catalog and approximately 750 million sources from the AllWISE Source Catalog (next up) with redshifts from the SDSS and other data in NED is increasing the holdings to over a billion distinct objects with cross-identifications, providing a rich resource for multi-wavelength research. Combining data across such large surveys, as well as integrating data from over 110,000 smaller but scientifically important catalogs and journal articles, presents many challenges including the need to update the computing infrastructure and tool production and operations on a regular basis. Integration of the Firefly toolkit into the new user interface is ushering in a new phase of interactive data visualization in NED, with features and capabilities familiar to users of IRSA and the emerging LSST science user interface. Graphical characterizations of NED content and estimates of completeness in different sky and spectral regions are also being developed. A newly implemented service that follows the Table Access Protocol (TAP) enables astronomers to issue queries to the NED object directory using Astronomical Data Language (ADQL), a standard shared in common with the NASA mission archives and other virtual observatories around the world. A brief review will be given of new science capabilities under development and planned for 2019-2020, as well as initiatives underway involving deployment of a parallel database, cloud technologies, machine learning, and first steps in bringing analysis capabilities close to the database in collaboration with IRSA. I will close with some questions for the community to consider in helping us plan future science capabilities and directions for NED in the 2020s.

Author(s): Joseph M. Mazzarella1
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Contributing team(s): NED Team

214.06 – New Developments At The Science Archives Of The NASA Exoplanet Science Institute
The NASA Exoplanet Science Institute (NExScI) at Caltech/IPAC is the science center for NASA’s Exoplanet Exploration Program and as such, NExScI operates three scientific archives: the NASA Exoplanet Archive (NEA) and Exoplanet Follow-up Observation Program Website (ExoFOP), and the Keck Observatory Archive (KOA).

The NASA Exoplanet Archive supports research and mission planning by the exoplanet community by operating a service that provides confirmed and candidate planets, numerous project and contributed data sets and integrated analysis tools. The ExoFOP provides an environment for exoplanet observers to share and exchange data, observing notes, and information regarding the Kepler, K2, and TESS candidates. KOA serves all raw science and calibration observations acquired by all active and decommissioned instruments at the W. M. Keck Observatory, as well as reduced data sets contributed by Keck observers.

In the coming years, the NExScI archives will support a series of major endeavours allowing flexible, interactive analysis of the data available at the archives. These endeavours exploit a common infrastructure based upon modern interfaces such as JupyterLab and Python. The first service will enable reduction and analysis of precision radial velocity data from the HIRES
Keck instrument. The Exoplanet Archive is developing a JupyterLab environment based on the HIRES PRV interactive environment. Additionally, KOA is supporting an Observatory initiative to develop modern, Python based pipelines, and as part of this work, it has delivered a NIRSPEC reduction pipeline. The ensemble of pipelines will be accessible through the same environments.

**Author(s):** G. Bruce Berriman
Institution(s): 1. Caltech/IPAC-NExScI

214.07 – The HEASARC in the 2020s
The High Energy Astrophysics Science Archive Research Center (HEASARC) is NASA’s primary archive for high energy astrophysics and cosmic microwave background (CMB) data, supporting the broad science goals of NASA’s Physics of the Cosmos theme. It provides vital scientific infrastructure to the community by standardizing science data formats and analysis programs, providing open access to NASA resources, and implementing powerful archive interfaces. These enable multimission studies of key astronomical targets, and deliver a major cost savings to NASA and proposing mission teams in terms of a reusable science infrastructure, as well as a time savings to the astronomical community through not having to learn a new analysis system for each new mission. The HEASARC archive holdings are currently in excess of 100 TB, supporting seven active missions (Chandra, Fermi, INTEGRAL, NICER, NuSTAR, Swift, and XMM-Newton), and providing continuing access to data from over 40 missions that are no longer in operation. HEASARC scientists are also engaged with the upcoming IXPE and XARM missions, and with many other Probe, Explorer, SmallSat, and CubeSat proposing teams. Within the HEASARC, the LAMBDA CMB thematic archive provides a permanent archive for NASA mission data from WMAP, COBE, IRAS, SWAS, and a wide selection of suborbital missions and experiments, and hosts many other CMB-related datasets, tools, and resources.

In this talk I will summarize the current activities of the HEASARC and our plans for the coming decade. In addition to mission support, we will expand our software and user interfaces to provide astronomers with new capabilities to access and analyze HEASARC data, and continue to work with our Virtual Observatory partners to develop and implement standards to enable improved interrogation and analysis of data regardless of wavelength regime, mission, or archive boundaries. The future looks bright for high energy astrophysics, and the HEASARC looks forward to continuing its central role in the community.

**Author(s):** Alan P. Smale
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214.08 – The role of Chandra in ten years from now and for the next few decades of astrophysical research

215 – Plenary Talk: An Era of Precision Astrophyics for Exoplanets, Stars, and the Milky Way, Keivan Stassun (Vanderbilt University)

215.01 – An Era of Precision Astrophysics for Exoplanets, Stars, and the Milky Way
While observing stars teaches us about the physical properties of the stars themselves, that knowledge also is the key to measuring the properties of nearly all exoplanets, and also the history of the Galaxy. Combining data from current and upcoming all-sky surveys, including Gaia, TESS, and the fifth Sloan Digital Sky Survey (SDSS-V), will enable accurate, empirical measurements of fundamental properties for millions of stars throughout the Milky Way—including an increase by four orders of magnitude in the number of stars with reliable parallaxes, two orders of magnitude in the number with ultraprecise light curves, and two orders of magnitude in the number with detailed chemical abundances. We demonstrate that stellar masses, radii, temperatures, distances, space motions, and detailed chemical abundances can now be measured with precisions of order 1%.

For almost twenty years, Chandra has advanced our understanding of the X-ray Universe by allowing astronomers to peer into a previously unexplored region of the high-energy observational parameters space. Thanks to its longevity, the mission has accumulated a large, unique body of observations whose legacy value, already tangible at this point, will only increase with time, and whose long-lasting influence extends well beyond the energy interval probed by Chandra. The Chandra archive, through the extensive characterization of the links between observations and literature, has measured the impact of Chandra on the astrophysical literature at a high level of granularity, providing striking evidence of how deeply and widely Chandra has impacted the advancement of both high-energy astrophysics and astronomical research from a multi-wavelength perspective.

In this talk, based on the missions that have been submitted for recommendation at the next decadal survey and the possible outcomes of the evaluation process, I will discuss how Chandra archival data can be used to anticipate the projected scientific success and long-lasting effects of a X-ray mission like Lynx or, differently, how they will become instrumental to maximize the scientific output of a new generation of facilities that will observe in different energies. I will argue that, in either scenario, the centrality of Chandra will extend well after the final demise of the mission and its data will continue serving the community in many different ways for the foreseeable future.

**Author(s):** Raffaele D’Abrusco
Institution(s): 1. Smithsonian Astrophysical Observatory

214.09 – The NASA Astrophysics Data System: Capabilities and Roadmap for the 2020s
The NASA Astrophysics Data System (ADS) is used daily by researchers and curators as a discovery platform for the Astronomy literature. Over the past several years, the ADS has been adding to the breadth and depth of its contents. Scholarly astronomy articles are now indexed as full-text documents, allowing for complete and accurate literature searches. High-level data products, data links, and software used in refereed astronomy papers are now also being ingested and indexed in our database. All the search functionality exposed in the new ADS interface is also available via its API, which we are continuing to develop and enhance. In this talk I will describe the current system, our current roadmap, and solicit input from the community regarding what additional data, services, and discovery capabilities the ADS should support.

**Author(s):** Alberto Accomazzi
Institution(s): 1. Harvard Smithsonian, Cfa
Contributing team(s): The ADS Team
216 – Astrophysics Archives in the 2020s Poster Session

216.01 – The First Data Release of the All-sky NOAO Source Catalog

Roughly three quarters of the sky has been imaged with NOAO’s telescopes from both hemispheres. While the large majority of these data were obtained for PI-led projects and surveys only a fraction have been released to the community via well-calibrated and easily accessible catalogs. We have remedied this by creating a catalog of sources from most of the public data taken on CTIO-4m+DECam as well as KPNO 4m+Mosaic3. The first data release (DR1) of this catalog, called the NOAO Source Catalog (NSC), contains 2.9 billion unique objects, 34 billion individual measurements, covers ~30,000 square degrees, has depths of ~23rd magnitude in most broadband filters with ~1-2% photometric accuracy and astrometric accuracy of ~2 mas. The NSC will be useful for exploring stellar streams, dwarf satellite galaxies, distant galaxies as well as variable stars and other transients. DR1 is now available through the NOAO Data Lab (datalab.noao.edu).

Author(s): David L. Nidever1
Institution(s): 1. Montana State University
Contributing team(s): NOAO Data Lab

216.02 – User recruitment, training, and support at NOAO Data Lab

The NOAO Data Lab (datalab.noao.edu) is a fully-fledged science data & analysis platform. However, simply building a science platform is not enough to declare it a success. Like any such system built for users, it needs actual users who see enough value in it to be willing to overcome the inertia of registering an account, studying the documentation, working through examples, and ultimately attempting to solve their own science problems using the platform. The NOAO Data Lab has been open to users since June 2016. In this past year we have registered hundreds of users and improved the system, not least through the interaction with and feedback from our users. The poster will delineate our efforts to recruit new users through conference presentations, platform demos and user workshops, and what we do to assure that users experience their first steps and their learning process with Data Lab as easy, competent, and inspiring. It will also present our efforts in user retention and user support, from a human-staffed helpdesk, to one-on-one sessions, to regular "bring-your-own-problem (BYOP)" in-house sessions with interested users.

Author(s): Robert Nikutta1, Michael J. Fitzpatrick1
Institution(s): 1. NOAO
Contributing team(s): NOAO Data Lab

216.03 – ESASky: All the sky you need

ESASky is a discovery portal giving to all astronomers, professional and amateur alike, an easy way to access high-quality scientific data from their computer, tablet, or mobile device. It includes over half a million images, 300,000 spectra, and more than a billion catalogue sources. From gamma rays to radio wavelengths, it allows users to explore the cosmos with data from a dozen space missions from the astronomical archives of ESA, NASA, and JAXA and does not require prior knowledge of any particular mission. ESASky features an all-sky exploration interface, letting users easily zoom in for stars as single targets or as part of a whole galaxy, visualise them and retrieve the relevant data taken in an area of the sky with just a few clicks. Users can easily compare observations of the same source obtained by different space missions at different times and wavelengths. They can also use ESASky to plan future observations with the James Webb Space Telescope, comparing the relevant portion of the sky as observed by Hubble and other missions. We will illustrate the many options to visualise and access astronomical data: interactive footprints for each instrument, tree-maps, filters, and solar-system object trajectories can all be combined and displayed. The most recent version of ESASky, released in February, also includes access to scientific publications, allowing users to visualise on the sky all astronomical objects with associated scientific publications and to link directly back to the papers in the NASA Astrophysics Data System.

Author(s): Guido De Marchi1
Institution(s): 1. European Space Agency
Contributing team(s): ESASky Team

217 – Laboratory Astrophysics Division Poster Session

217.01 – Fine-structure excitation of Fe II and Fe III due to collisions with electrons

Atomic data of iron peak elements are of great importance in astronomical observations. Among all the ionization stages of iron, Fe II and Fe III are of particular importance because of the high cosmic abundance, relatively low ionization potential and complex open d-shell atomic structure. Fe II and Fe III emission are observed from nearly all classes of astronomical objects over a wide spectral range from the infrared to the ultraviolet. To meaningfully interpret these spectra, astronomers have to employ highly complex modeling codes with reliable collision data to simulate the astrophysical observations. The major aim of this work is to provide reliable atomic data for diagnostics. We present new collision strengths and effective collisions for electron impact excitation of Fe II and Fe III for the forbidden transitions among the fine-structure levels of the ground terms. A very fine energy mesh is used for the collision strengths and the effective collision strengths are calculated over a wide range of electron temperatures of astrophysical importance (10-2000 K). The configuration interaction state wave functions are generated with a scaled Thomas-Fermi-Dirac-Amaldi (TFDA) potential, while the R-matrix plus intermediate coupling frame transformation (ICFT), Breit-Pauli R-matrix and Dirac R-matrix packages are used to obtain collision strengths. Influences of the different methods and configuration expansions on the collisional data are discussed. Comparison is made with earlier theoretical work and differences are found to occur at the low temperatures considered here.

This work was funded by NASA grant NNX15AE47G.

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217.02 – AtomDB Progress Report: Atomic data and new models for X-ray spectroscopy

The AtomDB project collects atomic data from both theoretical and observational/experimental sources, providing both a convenient interface
and its isotopologues is important for studying \( H_2 \) and \( D_2 \) and its \( H_2^+ \) and \( D_2^+ \) and its environment as varied as laboratory, of the formation of dust grains and aerosols from their gas-phase molecular precursors in environments exposed to intense UV radiation, such as the inner rim of a protoplanetary disk. Non-thermal populations of excited rovibrational levels can result, for example, following decay from electronically excited states to the electronic ground state. Competition between radiative decay and collisional processes.

**References:**


The authors acknowledge NASA SMD/APRA and SSW programs.

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### 217.03 – Li-Like CX

A fantastic discovery in 1996 caused an epiphany when it was realized that the charge exchange (CX) process was an important source of X-ray emission from comets. Over the last two decades, CX induced X-ray emission has been detected in a wide variety of solar and extra-solar sources. Recently, our group developed the Kronos database which contains CX cross sections and emission spectra for all H-like and most He-Like ions up to iron, based primarily on multichannel Landau-Zener calculations. Here we present preliminary results for extending Kronos to Li-like ions. Due to the incompleteness of highly-charged Li-like atomic structure data, we estimate missing energy levels and transition probabilities with a quantum defect approach and the package Autostructure. This work was support by NASA grants NNX13AF31G.

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### 217.04 – NASA Ames’ COSmIC Laboratory Astrophysics Facility: Recent Results and Progress

The COSmIC facility was developed at NASA Ames to study interstellar, circumstellar and planetary analogs in the laboratory \([1, 2]\). COSmIC stands for “Cosmic Simulation Chamber” and is dedicated to the study of molecules, ions and nanoparticles under the low temperature and high vacuum conditions that are required to simulate space environments. COSmIC integrates a variety of instruments that allow generating; processing and monitoring simulated space conditions in the laboratory. It is composed of a Pulsed Discharge Nozzle expansion that generates a plasma in a free supersonic jet expansion coupled to high-sensitivity, complementary in situ diagnostic tools, used for the detection and characterization of the species present in the expansion: a Cavity Ring Down Spectroscopy (CRDS) and fluorescence spectroscopy systems for photonic detection, and a Reflectron Time-Of-Flight Mass Spectrometer (ReTOF-MS) for mass detection \([3, 4]\).

Recent advances achieved in laboratory astrophysics using COSmIC will be presented, in particular in the domain of the diffuse interstellar bands (DIBs) \([5, 6]\) and the monitoring, in the laboratory, of the formation of dust grains and aerosols from their gas-phase molecular precursors in environments as varied as circumstellar outflows \([7]\) and planetary atmospheres \([8, 9, 10]\). Plans for future laboratory experiments on cosmic molecules and grains in the growing field of laboratory astrophysics (NIR-MIR CRDS, Laser Induced Fluorescence spectra of cosmic molecule analogs and the laser induced incandescence spectra of cosmic grain analogs) will also be addressed as well as the implications for astronomy.

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### 217.05 – Laboratory Measurements for H$_3^+$ Deuteration Reactions

Deuterated molecules are important chemical tracers of protostellar cores. At the ~10$^5$ cm$^{-3}$ particle densities and ~20 K temperatures typical for protostellar cores, most molecules freeze onto dust grains. A notable exception is H$_3^+$ and its isotopologues. These become important carriers of positive charge in the gas, can couple to any ambient magnetic field, and can thereby alter the cloud dynamics. Knowing the total abundance of H$_3^+$ and its isotopologues is important for studying the evolution of protostellar cores. However, H$_3^+$ and D$_3^+$ have no dipole moment. They lack a pure rotational spectrum and are not observable at protostellar core temperatures. Fortunately H$_2D^+$ and D$_2H^+$ have dipole moments and a pure rotational spectrum that can be excited in protostellar cores. Observations of these two molecules, combined with astrochemical models, provide information about the total abundance of H$_3^+$ and all its isotopologues. The inferred abundances, though, rely on accurate astrochemical data for the deuteration of H$_3^+$ and its isotopologues.

Here we present laboratory measurements of the rate coefficients for three important deuteration reactions, namely D + H$_3^+$/H$_2D^+$/D$_2H^+ \rightarrow H + H_2D^+$/D$_2H^+$/D$_3^+$. Astrochemical models currently rely on rate coefficients from classical (Langevin) or semi-classical methods for these reactions, as fully quantum-mechanical calculations are beyond current computational capabilities. Laboratory studies are the most tractable means of providing the needed data. For our studies we used our novel dual-source, merged fast-beams apparatus, which enables us to study reactions of neutral atoms and molecular ions. Co-propagating beams allow us to measure experimental rate coefficients as a function of collision energy. We extract cross section data from these results, which we then convolve with a Maxwell-Boltzmann distribution to generate thermal rate coefficients. Here we present our results for these three reactions and discuss some implications.


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(http://www.atomdb.org/Webguide/webguide.php) as well as providing input to spectral models for many types of astrophysical X-ray plasmas. We have released several updates to AtomDB in response to the Hitomi data, including new data for the Fe K complex, and have expanded the range of models available in AtomDB to include the Kronos charge exchange models from Mullen et al. (2016, ApJS, 224, 2). Combined with the previous AtomDB charge exchange model (http://www.atomdb.org/CX/), these data enable a velocity-dependent model for X-ray and EUV charge exchange spectra. We also present a new Kappa-distribution spectral model, enabling plasmas with non-Maxwellian electron distributions to be modeled with AtomDB. Tools are provided within pyAtomDB to explore and exploit these new plasma models. This presentation will review these enhancements and describe plans for the new few years of database and code development in preparation for XARM, Athena, and (hopefully) Arcus.
mostly due to H$_2$, determine the resulting rovibrational emission spectrum. For CN, and other open-shell molecules, the resulting spectrum will be complicated due to fine-structure splitting of the rotational levels. In some cases, fine-structure resolution has been previously computed for rotational transitions in atom- or diatom-diatom collisional processes. Here we present the first fine-structure resolution for vibrational deexcitation for CN colliding with H$_2$. The collisional cross sections were computed using a 6D potential energy surface with a full close-coupling approach. Fine-structure resolution is obtained by adopting an angular momentum recoupling scheme to transform the scattering matrices to a recoupled basis. Here we present low-energy calculations for the v=1 to 0 transition. This work was supported by NASA Grant NNX16AF09G.

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### 217.07 – UV-Visible Spectra of PAHs and Derivatives Seeded in Supersonic Jet. Astrophysical Implications

Laboratory absorption spectra of Polycyclic Aromatic Hydrocarbons (PAHs) and PAH derivatives measured under astrophysically relevant conditions are crucial to test the PAHs-DIBs hypothesis as well as the PAH model for the IR emission bands. Our dedicated experimental setup on the COSmic Simulation Chamber (COSmIC) provides an excellent platform to study neutral and ionized PAHs under the low temperature and pressure conditions that are representative of interstellar environments [1]. In this work, we study the effect of the substitution of CH bond(s) by a nitrogen atom(s) on the electronic spectra of phenanthrene. The electronic transitions associated with the lower excited states of neutral phenanthrene (C$_{14}$H$_{10}$) and phenanthridine (C$_{13}$H$_{14}$N) are measured in gas phase in the 315–345 nm region. Molecules are seeded in a supersonic expansion of argon gas and the absorption spectra are measured using the Cavity Ring Down Spectroscopy (CRDS) technique. Additional measurements of the absorption spectra of phenanthrene, phenantridine and 1,10-phenanthroline (C$_{12}$H$_{8}$N$_2$) isolated in 10 K argon matrices are also performed. The comparison between the CRDS spectra with the absorption of the matrix-isolated molecules highlight the matrix-induced perturbations in band position, profiles and broadening and illustrates the need of gas phase spectra for more accurate comparisons with astronomical spectra.


**Acknowledgements:** This research is supported by the APRA Program of NASA SMD

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### 217.08 – Quenching from highly-excited SiO rotational levels due to H$_2$ collision

Using a full quantum-mechanical close-coupling approach on a 4D rigid-rotor potential energy surface (PES), we performed scattering calculations for highly-excited rotational levels (j=6-10) of SiO for interactions with H$_2$ for the first time. Emission lines from highly excited SiO rotational levels are observed in a variety of environments including outflows from AGB stars. However, explicit collisional data are lacking for H$_2$ colliders, except for recent work from our group for j=1-5. Here we extend that work using a hybrid OpenMP/MPGi scattering code and a PES computed at the CCSD(T)-F12b level of theory. The H$_2$ and SiO bond lengths are fixed at their equilibrium values. The current results will allow for non-local thermodynamic models of SiO rotational emission from AGB stars.

This work was funded by NASA grant NNX16AF09G.

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### 217.09 – Properties of Highly Rotationally Excited H$_2$ in Photodissociation Regions

H$_2$ is the dominant molecular species in the vast majority of interstellar environments and it plays a crucial role as a radiative coolant. In photodissociation regions, it is one of the primary emitters in the near to mid-infrared which are due to lines originating from highly excited rotational levels. However, collisional data for rotational levels j>10 are sparse, particularly for H$_2$-H$_2$ collisions. Utilizing new calculations for para-H$_2$ and ortho-H$_2$ collisional rate coefficients with H$_2$ for j as high as 30, we investigate the effects of the new results in standard PDR models with the spectral simulation package Cloudy. We also perform Cloudy models of the Orion Bar and use Radex to explore rotational line ratio diagnostics. The resulting dataset of H$_2$ collisional data should find wide application to other molecular environments.

This work was supported by Hubble Space Telescope grant HST-AR-13899.001-A and NASA grants NNX15AI61G and NNX16AF09G.

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### 217.10 – The Titan Haze Simulation Experiment: Latest Laboratory Results and Dedicated Plasma Chemistry Model

Here, we present the latest results on the gas and solid phase analyses in the Titan Haze Simulation (THS) experiment. The THS experiment, developed at NASA Ames’ COSmIC facility is a unique experimental platform that allows us to simulate Titan’s complex atmospheric chemistry at Titan-like temperature (200 K) by cooling down N$_2$-CH$_4$-based mixtures in a supersonic expansion before inducing the chemistry by plasma.

**Gas phase:** The residence time of the jet-accelerated gas in the active plasma region is less than 4 µs, which results in a truncated gas phase that enables us to control how far in the chain of reactions the chemistry is processing. By adding heavier molecules in the initial gas mixture, it is then possible to study the first and intermediate steps of Titan’s atmospheric chemistry as well as specific chemical pathways, as demonstrated by mass spectrometry and comparison to Cassini CAPS data [1]. A new model was recently developed to simulate the plasma chemistry in the THS. Calculated mass spectra produced by this model are in good agreement with the experimental THS mass spectra, confirming that the short residence time in the plasma cavity limits the growth of larger species [2].

**Solid phase:** Scanning electron microscopy and infrared spectroscopy have been used to investigate the effect of the initial gas mixture on the morphology of the THS Titan aerosol analogs as well as on the level and nature of the nitrogen incorporation into these aerosols. A comparison to Cassini VIMS observational data has shown that the THS aerosols produced in simpler mixtures, i.e., that contain more nitrogen and where the N-incorporation is in isocyanide-type molecules instead of nitriles, are more representative of Titan’s aerosols [3]. In addition, a new optical constant facility has been developed at NASA Ames that allows us to determine the complex refractive indices of THS Titan aerosol analogs from NIR to FIR (0.76–222 cm$^{-1}$). The facility and preliminary results will be presented.

**References:**


**Acknowledgements:** This research is supported by the SSW Program of NASA SMD.
A, is a constant. The decrease in A/L constant. In the second set, L, while A varies, holding L constant. In the first set of the experiments, it is changed by varying A, while holding L constant. In the second set, A/L is changed by varying L, while holding A constant. The decrease in transmittance of the wave energy with increase in A/L, for both the above cases, are found to be agreement with each other.

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217.12 – Atomic kinetics of a neon photoionized plasma experiment at Z
We discuss an experimental effort to study the atomic kinetics in astrophysically relevant photoionized plasmas via K-shell line absorption spectroscopy. The experiment employs the intense x-ray flux emitted at the collapse of a Z-pinch to heat and backlight a photoionized plasma contained within a cm-scale gas cell placed at a variable distance from the Z-pinch and filled with neon gas pressures in the range from 3.5 to 30 Torr. The experimental platform affords an order of magnitude range in the ionization parameter characterizing the photoionized plasma at the peak of the x-ray drive from about 5 to 80 erg/cm²/s. Thus, the experiment allows for the study of trends in ionization distribution as a function of the ionization parameter. An x-ray crystal spectrometer capable of time-integrated and/or time-gated configurations is used to collect absorption spectra. The spectra show line absorption by several ionization stages of neon, including Be- , Li-, He-, and H-like ions. Analysis of these spectra yields ion areal densities and charge state distributions, which can be compared with simulation results from atomic kinetics codes. In addition, the electron temperature is extracted from level population ratios of nearby energy levels in Li- and Be-like ions, which can be used to test heating models of photoionized plasmas.

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Contributing team(s): ZAPP Collaboration

217.14 – Revisiting NLTE Rotational and Vibrational Excitation of CO in UV Irradiated Environments
Being the second most abundant molecule in the ISM, CO has been well observed and studied as a tracer for many astrophysical processes. Highly rovibrationally excited CO emission is used to reveal features in intense UV-irradiated regions such as the inner rim of protoplanetary disks, carbon star envelopes, and star forming regions. Collisional rate coefficients are crucial for non-local thermodynamic equilibrium (NLTE) molecular analysis in such regions, while data for high rovibrational levels for CO were previously unavailable. Here we revisit CO excitation properties with comprehensive collisional data including high rovibrational states (up to v=5 and J=40) colliding with H₂, H and He, in various NLTE astrophysical environments with the spectral modeling packages RADEX and Cloudy. We studied fine ratio diagnostics between low- and high-vibrational transitions with RADEX. Using Cloudy, we investigated molecular properties in complex environments, such as photodissociation regions and the outflow of the carbon star IRC+10216, illustrating the potential for utilizing high rovibrational NLTE analysis in future astrophysical modeling.

This work was supported by NASA Grants NNX15AI16G and NNX16AP09G.

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Models and observations suggest that particle aggregation at and beyond the snowline is aided by water ice. As icy particles play such a crucial role in the earliest stages of planet formation, many laboratory studies have explored their collisional properties across a wide range of parameters (particle size, impact velocity, temperature T, and pressure P).

However, not all of these parameters have always been varied systematically, leading to apparently contradictory results on collision outcomes. Previous experiments only agreed that a temperature dependence set in above \( \approx 210 \) K. Open questions remain as to what extent the structural properties of the particles themselves dictate collision outcomes. The P–T gradients in...
protoplanetary disks mean that the ices are constantly processed, undergoing phase changes between different solid phases and the gas phase. To understand how effectively collision experiments reproduce protoplanetary disk conditions, environmental impacts on particle structure need to be investigated.

We characterized the bulk and surface structure of icy particles used in collision experiments, exploiting the unique capabilities of the NIMROD neutron scattering instrument. Varying temperature at a constant pressure of around 30 mbar, we studied structural alterations to determine which of the observed properties matches the temperature dependencies observed in collisional behaviour.

Our icy grains are formed under liquid nitrogen and heated from 103 to 247 K. As a result, they undergo changes in the crystalline ice-phase, sublimation, sintering and surface pre-melting. An increase in the thickness of the diffuse surface layer from $\approx 10$ to $\approx 30 \AA$ (2.5 to 12 bilayers) suggests increased molecular mobility at temperatures above $\approx 210$ K.

Because none of the other changes ties in with the temperature trends in collisional outcomes, we conclude that the diffuse interface plays a key role in collision experiments at these temperatures. Consequently, the P–T environment may have a larger influence on collision outcomes than previously thought.

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218.04 – The ZEUS 1 & 2 INvestigated Galaxy Reference Sample (ZINGRS): A window into galaxies in the early Universe.

Galaxies have evolved significantly from the early Universe until today. Star formation rates, stellar and molecular gas masses, sizes and metal enrichment of galaxies have all changed significantly from early epochs until the present. Probing the physical conditions of galaxy at high redshift is vital to understanding this evolution. ZINGRS, the ZEUS 1 and 2 INvestigated Galaxy Reference Sample, provides a unique and powerful window for this work. The sample consists of more than ~30 galaxies from $z \sim 1 - 4.5$ for which the far-IR fine-structure lines (e.g. [CII] 158 micron, [NII] 122micron, [OIII] 88 micron) have been observed with the ZEUS-1 and 2 instruments. These lines are ideal for studying high-z systems since they require low energies for excitation, are typically optically thin, and are not

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susceptible to extinction from dust. ZINGRS is the largest collection of far-IR fine-structure line detections at high-z. Here we describe the sample, including extensive multifrequency supporting observations like CO & radio continuum, and summarize what we have learned so far.

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218.07 – ZINGRS: Understanding Hot DOGs via the resolved radio continuum of W2246-0526

We present new high-resolution (~0.5") radio-continuum images of the high-redshift galaxy W2246-0526 obtained with the Jansky Very Large Array. W2246 at z~4.6 is a hot dust obscured galaxy (Hot DOG) that have extreme luminosities, LIR > 10^{14} L_{\odot} produced by hot T~450 K dust. It hosts both an active galactic nucleus and significant star formation. Having observed the [OIII] 88 micron line from W2246 with our ZEUS spectrometer, the source is part of our ZEUS INvestigate Galaxy Reference Sample (ZINGRS). The radio images are initial observations from the ZINGRS Radio Survey where we observe the free-free and non-thermal emissions of high-z galaxies. Combining the radio emission with ALMA and ZEUS observations of the [CII] 158 micron, [OIII] 88 micron and [NII] 122 micron lines we probe the metallicity, age of stellar population, and ionization parameter. For W2246 we pay special attention to gradients of the stellar age and metallicity to determine the impact of the AGN on the host galaxy. Our work here is our initial analysis. When complete for all of ZINGRS ours findings will improve our understanding of early galaxies, including helping to explain Hot DOGs like W2246.

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218.08 – ZINGRS: CO2-1 observations of strong C+ emitters at z~2

We present new CO(2-1) line observations from NOEMA of five strong C+ emitting galaxies at high redshift. These galaxies, pulled from the Zeus INvestigated Galaxy Reference Sample (ZINGRS), were observed in their [CII] 158 micron line with the ZEUS instrument showing strong emission, 1 to 2% of their total far-IR luminosity. Our previous work suggests this emission is produced by normal star forming processes in photo-dissociation regions (PDRs), albeit on a galaxy wide scale fueled by cold-flow accretion. However, we could not fully exclude other mechanisms accounting for some or all of the emission. The work presented here, combining the CO emission with the [CII] 158 micron line, is consistent with PDRs being the source of the extreme C+ emission. It is further evidence for the existence of gas-rich galaxies in the early Universe undergoing galaxy-wide starbursts. These systems are not present in the nearby Universe, so represent a unique yet import evolutionary stage at early epochs.

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218.09 – Addressing the [O III] / Hβ offset in metal poor star forming galaxies found in the RESOLVE survey and ECO catalog

Metal poor star forming galaxies sit on the far left wing of the BPT diagram just below traditional demarcation lines. The basic approach to reproducing their emission lines by coupling photoionization models to stellar population synthesis models underestimates the observed [O III] / Hβ ratio by a factor 0.3-0.5 dex. We classified galaxies as metal poor in the RESOLVE Spectroscopy of a Local Volume (RESOLVE) survey and the Environmental Context (ECO) catalog by using the IZI code based off of Bayesian inference. We used a variety of stellar population synthesis codes to generate SEDs covering a range of starburst ages and metallicities including both secular and binary stellar evolution. Here, we show that multiple SPS codes can produce SEDs hard enough to reduce the offset assuming that simple, and perhaps unjustified, nebular conditions hold. Adopting more realistic nebular conditions shows that, despite the recent emphasis placed on binary evolution to fit high O III ratios, none of our SEDs can reduce the offset. We propose several new solutions including using ensembles of nebular clouds and improved microphysics to address this issue. This work is supported by National Science Foundation awards OCI-1053575, though XSEDE award TG-AST140040, and NSF awards AST-0953568 and CISE/ACI-1156614.

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Contributing team(s): RESOLVE survey team

218.10 – Post-Starburst Galaxies At The End of The E+A Phase

Post-starburst galaxies, once thought to be rare curiosities, are now recognized to represent a key phase in the galaxy evolution. The post-starburst, or E+A phase, should however not be considered as a single, short-lived phenomenon; rather, it is an extended evolutionary process that occurs as galaxy transitions from an actively star-forming system into a quiescent one. We present a study of nearby galaxies at or near the end of the E+A phase, wherein all star formation has been quenched, the fossilized stellar population of the most recent starburst is highly localized, and the remainder of the galaxy’s stellar population is old and quiescent. The luminosity and stellar age distribution of these “end-phase E+As” can provide insights into the evolution of galaxies onto and within the red sequence, from active to passive systems. This work is supported by National Science Foundation grants to CUNY College of Staten Island and the American Museum of Natural History; the College of Staten Island Office of Academic Affairs; the Sherman Fairchild Science Pathways Scholars Program (SP"2) at Barnard College; and the Alfred P. Sloan Foundation.

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Contributing team(s): SDSS-IV Collaboration

219 – Molecular Clouds, Star Formation and YSOs Poster Session
219.01 – Using Hyperfine Structure Limits to Characterize the Formaldehyde Maser in G32.74-0.07

Formaldehyde (H$_2$CO) masers are a rare variety of astrophysical masers, but they have the virtue of exclusively tracing the interiors of high-mass star forming regions. We report observations conducted with the 305m Arecibo Telescope and the Karl G. Jansky Very Large Array (VLA) of the 6 cm H$_2$CO maser in the region of high-mass star formation G32.74-0.07. This maser is among the narrowest H$_2$CO masers known, and thus it is an excellent candidate to study the excitation of the hyperfine components of the transition. The Arecibo and VLA results are consistent, the maser flux density observed with Arecibo is recovered in the VLA image within the rms noise of the spectra, and the fitted line widths of the two observations agree to within formal errors. Our high signal-to-noise (≈7 mJy rms) and high spectral resolution (0.05 km/s) observations allow us to set strong limits on the hyperfine structure of the line. The line profile is consistent with unsaturated emission, with a maser gain of approximately 3, and an amplified background radio continuum of ~1 mJy. VLA observations confirm the presence of a continuum source at the location of the maser. The continuum source is characterized by a spectral index of +0.9 at 5 GHz, which is indicative of thermal Bremsstrahlung in the optically thick/thin transition.

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219.02 – VUV spectroscopy of OH and SO

Radicals are certainly important in the ISM and atmospheric chemical cycles but laboratory measurement of their photoabsorption and dissociation cross sections is a continuing challenge. In some cases, the detailed rovibrational structure within ultraviolet electronic transitions leads to interesting resonance or isotope effects in interstellar or atmospheric photodissociation but their measurement requires high spectral resolution. The latest generation in broadband high-resolution UV spectrometers at the SOLEIL synchrotron has been put to work studying the photoabsorption of radicals OH and SO. I will present the results of these studies.

This unique UV/VUV Fourier-transform spectrometer is illuminated by a 3rd generation synchrotron and a column of radicals is maintained in a radio-frequency discharge [1]. Careful separation of precursor gases and contaminants is needed to distinguish the radical absorption, and a means of determining the absolute radical column density. In the case of OH, we measure the absolute absorption strength of the D-X transition, occasionally observed in the ISM and refine its rate of interstellar photodissociation [2]. For SO, we measure the absorption strength and variable predissociation linewidths of the B-X transition, and investigate the possibility of isotope-dependent effects.


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219.03 – Seeing High Velocity Clouds and Turbulent Mixing Layers in the Ultraviolet: Predictions from Hydrodynamic Simulations

High velocity clouds (HVCs) and turbulent mixing layers (TMLs) emit light across a wide range of wavelengths. In order to aid in the detection of their ultraviolet emission, we predict the UV emission line intensities emitted by C II, C III, C IV, N II, N III, N IV, N V, O III, O IV, O V, O VI, Si II, Si III, and Si IV in a variety of simulated HVCs and TMLs. These predictions are based on detailed hydrodynamic simulations made with the FLASH code and employing non-equilibrium ionization calculations for carbon, nitrogen, oxygen, and silicon. The results are compared with FUSE and SPEAR/FIMS observations and with predictions from other models of hot/cold interfaces. We also present methods for scaling the results so that they can be applied to more or less dense environments.

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219.04 – The Argus+ Project: Wide-field, high-resolution 3mm molecular imaging with the Green Bank Telescope

Argus+ is a large format radio camera system for the Green Bank Telescope (GBT) that will carry out high-fidelity spectroscopic mapping in the molecule-rich 3mm band. The project builds on the success of the prototype 16-pixel Argus 3mm receiver. Argus+ will be nine copies of Argus in a single dewar, with lower noise amplifiers, for an increase of a factor of ten in mapping speed. The Argus+ project includes a dedicated spectrometer and improvements to the GBT metrology that will more than double the amount of useful observing time at 3mm. With a footprint of 6′x6′, 144 pixels, an angular resolution of 6″ to 8″, and the sensitivity of a filled aperture, Argus+ will map fundamental transitions of important species over hundreds of square arc-min with a spatial dynamic range of 10$^{4}$ to 10$^{5}$. The Argus+ project includes two legacy surveys: a survey of molecules in the Gould Belt molecular clouds, and a survey of dense gas in nearby galaxies. These will be carried out by the scientific community and will be defined through a series of workshops. The Project has a strong educational component and will involve undergraduates at every stage. It will be incorporated into new and existing outreach programs, and will produce materials for the Green Bank Science Center. Argus+ will be operated as an open skies facility of the Green Bank Observatory, with the majority of its use being allocated through the normal proposal review process.

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219.05 – Formaldehyde in the Diffuse Interstellar Cloud MBM40

MBM40, a high-latitude molecular cloud, has been extensively studied using different molecular tracers. It appears that MBM40 is composed of a relatively dense, helical filament embedded in a more diffuse substrate of low density molecular gas. In order to study the transition between the two regimes, this project presents the first high-resolution mapping of MBM40 using the 1$^{13}$CO hyperfine transition of formaldehyde (H$_2$CO) at 4.83 GHz. We used H$_2$CO spectra obtained with the Arecibo telescope more than a decade ago to construct this map. The results can be compared to previous maps made from the CO(1-0) transition to gain further understanding of the structure of the cloud. The intensity of the H$_2$CO emission was compared to the CO emission. Although a correlation exists between the H$_2$CO and CO emissivity, there seems to be a saturation of H$_2$CO line strength for stronger CO emissivity. This is probably a radiative transfer effect of the CO emission. We have also found that the velocity dispersion of H$_2$CO in the lower ridge of the cloud is significantly lower than in the rest of the cloud. This may indicate that this portion of the cloud is a coherent structure (analogous to an eddy) in a turbulent flow.

Author(s): Mackenzie Joy$^1$, Lori A. Magnani$^1$
Institution(s): 1. University of Georgia
219.06 – Determining the Nature of [CII] 158 Micron Emission: an Improved Star Formation Rate Indicator

The brightest observed emission line from most normal star-forming galaxies is the 158 micron line arising from singly-ionized carbon (also known as C+ or CII). In fact, astronomers have recently begun using the bright emission line to detect and characterize galaxies in the furthest reaches of the universe. It is thus imperative that we have the tools to fully understand how this emission line could be utilized as an indicator of star formation rate, a primary parameter by which galaxies and their constituent star-forming regions are characterized. There are two main challenges to utilizing the [CII] 158 micron line as a star formation rate indicator. First, advances in long-wavelength astronomical instrumentation have only recently enabled its detection in statistically-significant samples of galaxies. Second, it is both a blessing and a curse that singly-ionized carbon can be created in both star-forming regions (ionized HI regions) and in non-star forming regions (neutral photo-dissociation regions). In order to better understand and quantify the [CII] emission as an indicator of star-formation rate, the relationship between the [NI] 205 micron emission, which can only arise from the ionized interstellar medium (ISM), and the [CII] 158 micron emission has been employed to determine the fraction of [CII] emission that originates from each phase of the ISM. Sub-kiloparsec measurements of the [NI] 205 micron line in nearby galaxies have recently become available as part of the KINGFISH program. We use these two far-infrared lines along with the full suite of KINGFISH panchromatic data to present an improved calibration of the [CII] emission line as a star formation rate indicator.

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Contributing team(s): KINGFISH Team

219.07 – Resolved Star Formation in Galaxies Using Slitless Spectroscopy

The ability to spatially resolve individual star-formation regions in distant galaxies and simultaneously extract their physical properties via emission lines is a critical step forward in studying the evolution of galaxies. While efficient, deep slitless spectroscopic observations offer a blurry view of the summed properties of galaxies. We present our studies of resolved star formation over a wide range of redshifts, including high redshift Ly-a sources. The unique capabilities of the WFC3 IR Grism and our two-dimensional emission line method (EM2D) allows us to accurately identify the specific spatial origin of emission lines in galaxies, thus creating a spatial map of star-formation sites in any given galaxy. This method requires the use of multiple position angles on the sky to accurately derive both the location and the observed wavelengths of these emission lines. This has the added benefit of producing better defined redshifts for these sources. Building on our success in applying the EM2D method towards galaxies with [OII], [OIII], and Ha emission lines, we have also applied EM2D to high redshift (z>6) Ly-a emitting galaxies. We are also able to produce accurate 2D emission line maps (MAP2D) of the Ly-a emission in WFC3 IR grism observations, looking for evidence that a significant amount of resonant scattering is taking place in high redshift galaxies such as in a newly identified z=7.5 Faint Infrared Galaxy Survey (FIGS) Ly-a galaxy.

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Contributing team(s): FIGS

219.08 – Optical Monitoring of Young Stellar Objects

Observing Young Stellar Objects (YSOs) for variability in different wavelengths enables us to understand the evolution and structure of the protoplanetary disks around stars. The stars observed in this project are known YSOs that show variability in the Infrared. Targets were selected from the Spitzer Space Telescope Young Stellar Object Variability (YSOVAR) Program, which monitored star-forming regions in the mid-infrared. The goal of our project is to investigate any correlation between the variability in the infrared versus the optical. Infrared variability of YSOs is associated with the heating of the protoplanetary disk while accretion signatures are observed in the H-alpha region. We used the University of Wyoming’s Red Buttes Observatory to monitor these stars for signs of accretion using an H-alpha narrowband filter and the Johnson-Cousins filter set, over the Summer of 2017. We perform relative photometry and inspect for an imaging light variation by observing these targets for a period of four months every two to three nights. The study helps us better understand the link between accretion and H-alpha activity and establish a disk-star connection.

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Institution(s): 1. University of Wyoming

219.09 – UV, X-ray, and Optical Variability of the Young Star T Cha Produced by Inner Disk Obscuration: Results from a Coordinated HST, XMM-Newton, LCOGT, and SMARTS Observing Campaign

The young (7 Myr) 1.5 solar mass T Tauri star T Chamaeleontis shows dramatic variability. The optical extinction varies by at least 3 magnitudes on few hour time-scales with no obvious periodicity. The obscuration is produced by material at the inner edge of the circumstellar disk and therefore characterizing the absorbing material can reveal important clues regarding the transport of gas and dust within such disks. The inner disk of T Cha is particularly interesting, because T Cha has a transitional disk with a large gap at 0.2-15 AU in the dust disk and allows study of the gas and dust structure in the terrestrial planet formation zone during this important rapid phase of protoplanetary disk evolution. For this reason we have conducted a major multi-spectral-region observing campaign to study the UV/X-ray/optical variability of T Cha. During 2018 February/March we monitored the optical photometric and spectral variability using LCOGT (Chile/South Africa/Australia) and the SMARTS telescopes in Chile. These optical data provide a broad context within which to interpret our shorter UV and X-ray observations. We observed T Cha during 3 coordinated observations (each 5 HST orbits + 25 ksec XMM; on 2018 Feb 22, Feb 26, Mar 2) using the HST COS/STIS spectrographs to measure the FUV/NUV spectra and XMM-Newton to measure the corresponding X-ray energy distribution. The observed spectral changes are well correlated and demonstrate the influence of the same absorbing material in all the spectral regions observed. By examining which spectral features change and by how much we can determine the location of different emitting regions relative to the absorbers along the line-of-sight to the star. In this poster we provide an overview of the variability seen in the different spectral regions and quantify the dust and gas content of T Cha’s inner disk edge.

This work is supported by grant HST-GO-15128 and time awarded by HST, XMM-Newton, LCOGT, and SMARTS. We acknowledge the assistance provided by Dr. Todd Henry in conducting this observing campaign.

Author(s): Alexander Brown1, Kevin France5, Frederick M. Walter6, P. Christian Schneider2, Timothy M. Brown4, Sean M. Andrews3, David J. Wilner3
220.01 – The ALFALFA Extragalactic Catalog and Data Processing Pipeline

The Arecibo Legacy Fast ALFA 21cm HI Survey has reached completion. The observations and data are used by team members and the astronomical community in a variety of scientific initiatives with gas-rich galaxies, cluster environments, and studies of low redshift cosmology. The survey covers nearly 7000 square degrees of high galactic latitude sky visible from Arecibo, Puerto Rico and ~4400 hours of observations from 2005 to 2011. We present the extragalactic HI source catalog of over ~31,000 detections, their measured properties, and associated derived parameters. The observations were carefully reduced using a custom made data reduction pipeline and interface. Team members interacted with this pipeline through observation planning, calibration, imaging, source extraction, andcataloging. We describe this processing workflow as it pertains to the complexities of the single-dish multi-feed data reduction as well as known caveats of the source catalog and spectra for use in future astronomical studies and analysis. The ALFALFA team at Cornell has been supported by NSF grants AST-0607007, AST-1107390 and AST-1714828 and by grants from the Brinson Foundation.

Author(s): Brian R. Kent, Martha P. Haynes, Riccardo Giavalisco
Institution(s): 1. Cornell University, 2. NRAO
Contributing team(s): The ALFALFA Team

220.02 – WFIRST Science Operations at STScI

With sensitivity and resolution comparable the Hubble Space Telescope, and a field of view 100 times larger, the Wide Field Instrument (WFI) on WFIRST will be a powerful survey instrument. STScI will be the Science Operations Center (SOC) for the WFIRST Mission, with additional science support provided by the Infrared Processing and Analysis Center (IPAC) and foreign partners. STScI will schedule and archive all WFIRST observations, calibrate and produce pipeline-reduced data products for imaging with the Wide Field Instrument, support the High Latitude Imaging and Supernova Survey Teams, and support the astronomical community in planning WFI imaging observations and analyzing the data. STScI has developed detailed concepts for WFIRST operations, including a data management system integrating data processing and the archive which will include a novel, cloud-based framework for high-level data processing, providing a common environment accessible to all users (STScI operations, Survey Teams, General Observers, and archival investigators). To aid the astronomical community in examining the capabilities of WFIRST, STScI has built several simulation tools. We describe the functionality of each tool and give examples of its use.

Author(s): Karoline Gilbert
Institution(s): 1. Space Telescope Science Institute
Contributing team(s): the STScI WFIRST Team

220.03 – Using Deep Learning for Gamma Ray Source Detection at the First G-APD Cherenkov Telescope (FACT)

Finding gamma-ray sources is of paramount importance for Imaging Air Cherenkov Telescopes (IACT). This study looks at using deep neural networks on data from the First G-APD Cherenkov Telescope (FACT) as a proof-of-concept of finding gamma-ray sources with deep learning for the upcoming Cherenkov Telescope Array (CTA). In this study, FACT’s individual photon level observation data from the last 5 years was used with convolutional neural networks to determine if one or more sources were present. The neural networks used various architectures to determine which architectures were most successful in finding sources. Neural networks offer a promising method for finding faint and extended gamma-ray sources for IACTs. With further improvement and modifications, they offer a compelling method for source detection for the next generation of IACTs.

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220.04 – Improving Optical Absorption Models for Harsh Planetary Atmospheres: Laboratory Spectroscopy at Venus Surface Conditions

Modelling absorption spectra in high pressure, high temperature environments is complicated by the increased relevance of higher order collisional phenomena (e.g. line mixing, collision-induced absorption, finite duration of collisions) that alter the spectral lineshape. Accurate reference spectroscopy in these conditions is of interest for mineralogy and radiative transfer studies of Venus as well as other dense planetary atmospheres. We present a new, high pressure, high temperature absorption spectroscopy facility at the University of Colorado Boulder. This facility employs a dual frequency comb absorption spectrometer to record broadband (500nm), high resolution (~0.002nm) spectra in conditions comparable to the Venus surface (730K, 90bar). Measurements of the near-infrared spectrum of carbon dioxide at high pressure and temperature will be compared to modeled spectra extrapolated from the HITRAN 2016 database as well as other published models that include additional collisional physics. This comparison gives insight into the effectiveness of existing absorption databases for modeling the lower Venus atmosphere as well as the need to expand absorption models to suit these conditions.

Author(s): Ryan Kenneth Cole, Paul James Schroeder, Anthony Diego Draper, Gregory Brian Rieker
Institution(s): 1. University of Colorado Boulder

220.05 – Photometric Assessment of Night Sky Quality over Chaco Culture National Historical Park

The US National Park Service (NPS) characterizes night sky conditions over Chaco Culture National Historical Park using measurements in the park and satellite data. The park is located near the geographic center of the San Juan Basin of northwestern New Mexico and the adjacent Four Corners state. In the park, we capture a series of night sky images in V-band using our mobile camera system on nine nights from 2001 to 2016 at four sites. We perform absolute photometric calibration and determine the image placement to obtain multiple 45-million-pixel mosaic images of the entire night sky. We also model the regional night sky conditions in and around the park based on 2016 VIIRS satellite data. The average zenith brightness is 21.5 mag/arcsec², and the whole sky is only ~16% brighter than the natural conditions. The faintest stars visible to naked eyes have magnitude of approximately 7.0, reaching the sensitivity limit of human eyes. The main impacts to Chaco’s night sky quality are the light domes from Albuquerque, Rio Rancho, Farmington, Bloomfield, Gallup, Santa Fe, Grants, and Crown Point. A few of these light domes exceed the natural brightness of the Milky Way. Additionally, glare sources from oil and gas development sites are visible along the north and east horizons. Overall, the night sky quality at Chaco Culture National Historical Park is very good. The park preserves to a large extent the natural illumination cycles, providing a refuge for crepuscular and nocturnal species. During clear and dark nights, visitors have an opportunity to see the Milky Way from nearly horizon to horizon, complete constellations, and faint astronomical objects and natural sources of light such as the Andromeda Galaxy, zodiacal light, and airglow.

Author(s): Li-Wei Hung, Dan M Duriscoe, Jeremy M White, Bob Meadows, Sharolyn J Anderson
221 – Laboratory Astrophysics Division iPoster Session

221.01 – Interferometric analysis of laboratory photoionized plasmas utilizing supersonic gas jet targets.

Photoionized plasmas are an important component of active galactic nuclei, x-ray binary systems and other astrophysical objects. Laboratory produced photoionized plasmas have mainly been studied at large scale facilities, due to the need for high intensity broadband x-ray flux. Using supersonic gas jets as targets has allowed university scale pulsed power generators to begin similar research. The two main advantages of this approach with supersonic gas jets include: possibility of a closer location to the x-ray source and no attenuation related to material used for containment and or tamping. Due to these factors, this experimental platform creates a laboratory environment that more closely resembles astrophysical environments. This system was developed at the Nevada Terawatt Facility using the 1 MA pulsed power generator Zebra. Neon, argon, and nitrogen supersonic gas jets are produced approximately 7-8mm from the z-pinch axis. The high intensity broadband x-ray flux produced by the collapse of the z-pinch wire array implosion irradiates the gas jet. Cylindrical wire arrays are made with 4 and 8 gold 10µm thick wire. The z-pinch radiates approximately 12-16kJ of x-ray energy, with x-ray photons under 1keV in energy. The photoionized plasma is measured via x-ray absorption spectroscopy and interferometry. A Mach-Zehnder interferometer is used to measure the neutral density of the jet prior to the zebra shot at a wavelength of 266 nm. A dual channel air-wedge shearing interferometer is used to measure electron density of the ionized gas jet during the shot, at wavelengths of 532nm and 266nm. Using a newly developed interferometric analysis tool, average ionization state maps of the plasma can be calculated. Interferometry for nitrogen and argon show an average ionization state in the range of 3-8. Preliminary x-ray absorption spectroscopy collected show neon absorption lines. This work was sponsored in part by DOE Office of Science Grant DE-SC0014451.

Author(s): Kyle James Swanson1, Vladimir Ivanov1, Roberto Mancini1, Daniel C. Mayes1
Institution(s): 1. University of Nevada Reno

221.02 – Measurement of emission cross sections for n = 3 → 2 transitions in Neon-like Fe XVII and Ni XIX ions.

The absolute excitation cross sections of the strong $1s^2 2s^2 2p^5 1/2 3d^3/2 1P_1 \rightarrow 1s^2 2s 2p^6 1S_0$ and $1s^2 2s^2 2p^5 3/2 1d_5/2 \rightarrow 1s^2 2s 2p^6 1S_0$ strong resonance and intercombination lines, commonly known as $3C$ and $3D$, have been measured in neon-like Fe$^{16+}$ and Ni$^{18+}$. These measurements were carried out at the Lawrence Livermore National Laboratory’s EBIT-I electron beam ion trap facility using the EBIT Calorimeter Spectrometer (ECS) quantum microcalorimeter and a flat crystal spectrometer. The absolute excitation cross sections were determined by normalizing the measured spectrum to the X-ray emission from radiative recombination. The direct excitation lines $3C$ and $3D$ and radiative recombination (RR) lines were measured simultaneously using the ECS. By normalizing the measured RR flux to their theoretical cross sections, the emission from lines $3C$ and $3D$ was made absolute. Using simultaneous measurements from the higher resolution flat crystal spectrometer, it was possible to check for potential blends from lower charge states. Results of our measurements including comparison to theory, will be presented.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Author(s): Tom Lockard1, Gregory V. Brown1, Natalie Hell1, J.H. Scofield1, Peter Beiersdorfer1, Frederick Scott Porter2, Caroline Kilbourne2, Richard L. Kelley2, Maurice A. Leutenegger2, Gabriele Betancourt-Martinez2
Institution(s): 1. LLNL, 2. NASA/GSFC

222 – Molecular Clouds, Star Formation and Disks

222.01 – Chemistry of Protostellar Envelopes and Disks

Molecule formation is dynamic during the protostar collapse phase, driven by changes in temperature, density, and UV radiation as gas and dust flows from the envelope onto the forming protoplanetary disk. In this work, we compare physical models based on two different collapse solutions. We modeled the chemistry (created by Karen Willacy) for C180 to see how its abundance changes over time using as primary input parameters the temperature and density profile that were produced by the dust Radiative Transfer (MCRT) model called HOCHUNK3D from Whitney (2003). Given this model, we produce synthetic line emission maps from L1527 IRS to simulate the Class 0/I protostar L1527 IRS using RADMC3D code and compare them with previous observations from ALMA. High concentrations of gas phase molecules of C18O are found within the 20 AU in areas in the envelope that are close to the surface of the disk. In the outermost part of the disk surface, the C18O freezes out below 400 AU, showing a much reduced abundance where the temperature profile drops down below 25 K. In cold regions, the radiation field plays an important role in the chemistry.

Author(s): Lixandra Flores Rivera1, Susan Terebey1, Karen Willacy2
Institution(s): 1. California State University Los Angeles, 2. Jet Propulsion Laboratory

222.02 – Refining Models of L1527-IRS

This project examines the Class 0/Class 1 protostar L1527-IRS (hereby referred to as L1527) in the interest of creating a more accurate computational model. In a Class 0/Class 1 protostar like L1527, the envelope is massive, the protostar is growing in mass, and the disk is a small fraction of the protostar mass. Recent work based on ALMA data indicates that L1527, located in the constellation Taurus (about 140 parsecs from Earth), is about ~0.44 solar masses. Existing models were able to fit the spectral energy distribution of L1527 by assuming a puffed-up inner disk. However, the inclusion of the puffed-up disk results in a portion of the disk coinciding with the outflow cavities, a physically unsatisfying arrangement. This project tests models which decrease the size of the disk and increase the density of the outflow cavities (hypothesizing that some dust from the walls of the outflow cavities is swept up into the cavity itself) against existing observational data, and finds that these models fit the data relatively well.

Author(s): Elizabeth Baker Metzler-Winslow1, Susan Terebey1
Institution(s): 1. California State University, Los Angeles

222.03 – Why is the Magellanic Stream so Turbulent? - A Simulational Study

YSOs iPoster Session

L1527, the envelope is massive, the protostar is growing in mass, and the disk is a small fraction of the protostar mass. Recent work based on ALMA data indicates that L1527, located in the constellation Taurus (about 140 parsecs from Earth), is about ~0.44 solar masses. Existing models were able to fit the spectral energy distribution of L1527 by assuming a puffed-up inner disk. However, the inclusion of the puffed-up disk results in a portion of the disk coinciding with the outflow cavities, a physically unsatisfying arrangement. This project tests models which decrease the size of the disk and increase the density of the outflow cavities (hypothesizing that some dust from the walls of the outflow cavities is swept up into the cavity itself) against existing observational data, and finds that these models fit the data relatively well.

Author(s): Elizabeth Baker Metzler-Winslow1, Susan Terebey1
Institution(s): 1. California State University, Los Angeles

222.03 – Why is the Magellanic Stream so Turbulent? - A Simulational Study

As the Large and Small Magellanic Clouds travel through the Milky Way (MW) halo, gas is tidally and ram pressure stripped from them, forming the Leading Arm (LA) and Magellanic Stream (MS). The evolution of the LA and MS are an interest to astronomers because there is evidence that the diffuse gas that has been stripped off is able to fall onto the galactic disk and cool enough to fuel star formation in the MW. For et al, 2014 published a catalog of 251 high velocity clouds (HVCs) in the MS, many of which have head-tail morphologies, suggesting interaction with the Milky Way’s halo or other gas in the MS. For
et al noticed that the pointing direction of the HVCs are random, which they interpreted as an indication of strong turbulence. They suggested the shock cascade scenario as a contributing process, where ablated cloud material generates turbulence (and H-alpha emission). We take a closer look at this process via simulations. We ran numerical simulations of clouds in the MS using the University of Chicago’s FLASH software. We simulated cases that had two clouds, where one trailed behind the other, and we simulated cases that had one cloud in order to examine the effects of drafting on cloud dynamics and velocity dispersion. Initial cloud temperatures ranged from 100 K to 20,000 K. We have created velocity dispersion maps from the FLASH simulation data to visualize turbulence. We compare these generated maps with 21 cm observations (most recently Westmeier, 2017), in order to search for signatures similar to the small scale turbulence seen in the simulations. We find that if the clouds are initially near to each other, then drafting allows the trailing cloud to catch the leading cloud and mix together. For greater separations, Kelvin-Helmholtz instabilities disrupt the clouds enough before impact that drafting has a minimal role. Our velocity dispersion maps of the warmer clouds closely match values published in For et al, 2014; although, thermal broadening accounts for a large fraction of the velocity dispersion found in the generated maps.

Author(s): Elliott Williams¹, Robin L. Shelton²
Institution(s): 1. University of Georgia

222.04 – Hydride Molecules towards Nearby Galaxies
Observations carried out by the Herschel Space Observatory revealed strong spectroscopic signatures from light hydride molecules within the Milky Way and nearby active galaxies. To better understand the chemical and physical conditions of the interstellar medium, we conducted the first comprehensive survey of hydrogen fluoride (HF) and water molecular lines observed through the SPIRE Fourier Transform Spectrometer. By collecting and analyzing the sub-millimeter spectra of over two hundred sources, we found that the HF J = 1 - 0 rotational transition which occurs at approximately 1232 GHz was detected in a total of 39 nearby galaxies both in absorption and emission. The analysis will determine the main excitation mechanism of HF in nearby galaxies and provide steady templates of the chemistry and physical conditions of the ISM to be used in the early universe, where observations of hydrides are more scarce.

Author(s): Raquel R. Monje², Ngoc La¹, Paul Goldsmith²
Institution(s): 1. Golden West College, 2. JPL-Caltech

222.05 – Understanding Polarization in the Interstellar Medium Through the Theory of Radiative Torque Alignment
Although it is known that the dust grains in the ISM align with magnetic fields, the alignment physics of these particles is still somewhat unclear. Utilizing direct observational data and Radiative Alignment Torque (RAT) theory, further constraints can be put onto this alignment. Due to the physics of this alignment, there is a linear relationship between the extinction of the light seen through a dust cloud (Aν) and the wavelength of maximum polarization. A previous study, focusing on the Taurus cloud, found that there is a second, steeper relationship seen beyond an extinction of about four magnitudes, likely due to grain growth, in addition to the original linear relationship. We present early results from observations of low-to-medium extinction lines of sight in the starless cloud L183 (aka L134N), aimed at testing the Taurus results. We are currently extending the survey of stars behind L183 to higher extinctions to better probe the origins of the bifurcation seen in the Taurus results.

Author(s): Miranda Caputo¹, B-G Andersson², Kristin Rose Kulas³
Institution(s): 1. Santa Clara University, 2. USRA

223 – Surveys, Computation & Other Topics iPoster Session

223.01 – SAFARI: Searching Asteroids For Activity Revealing Indicators
We present results on one of the deepest and widest systematic searches for active asteroids, objects in the main-belt which behave dynamicaly like asteroids but display comet-like comae. This activity comes from a variety of sources, such as the sublimation of ices or rotational breakup, the former of which offers an opportunity to study a family of protoplanetary ices different than those seen in comets and Kuiper Belt objects. Indications of activity may be detected through visual or spectroscopic evidence of gas or dust emissions. However, these objects are still poorly understood, with only about 25 identified to date. We looked for activity indicators with a pipeline that examined ~35,000 deep images taken with the Dark Energy Camera (DECam) mounted on the 4-meter Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile. Our pipeline was configured to perform astrometry on DECam images and produce thumbnail images of known asteroids in the field to be examined by eye for signs of activity. We detected three previously identified active asteroids, one of which has shown repeated signs of activity in these data. Our proof of concept demonstrates 1) our novel informatics approach can locate active asteroids 2) DECam data are well suited to search for active asteroids. We will discuss the design structure of our pipeline, adjustments that had to be made for the specific dataset to improve performance, and the the significance of detecting activity in the main-belt. The authors acknowledge funding for this project through NSF grant number AST-1461200.

Author(s): Anthony Curtis², Colin Orion Chandler², Michael Mommet², Scott Sheppard¹, Chadwick A. Trujillo²

223.02 – Sky Of Stars: Visualizing Gaia Data in the Fiske Planetarium
ESA’s satellite Gaia has collected and continues to collect data about the positions, kinematics, and luminosity of more than one billion stars. This census is the most accurate census of the Milky Way to this day. The Fiske Planetarium at the University of Colorado hosts a state-of-the-art 8K projector and the ability to render the 3D positions of stars in real time. Using Python, Astropy and ADQL, I wrote tools to explore the Gaia data, creating different ways to visualize this three-dimensional map of our Galaxy. I created catalogs that the Fiske planetarium can read and project, including millions of stars that our naked eyes can’t see. For the first time ever, we are able to show in the planetarium what the sky would look like if our eyes were 10X, 100X, or 1000X bigger than they really are. With accurate positions and proper motions, we can also jump in time and roughly observe what our sky will look like in a thousand or in a million years. This catalog is now used in classes and talks, so students and planetarium visitors are able to travel through these stars and observe what they have looked like or what they will look like as the years go by.

Author(s): Luz Ibarra Perez¹, Zachary K. Berta-Thompson¹, Nickolas Alexander Conant³
Institution(s): 1. University of Colorado at Boulder

223.03 – Quantifying and Reducing Light Pollution
We describe the current level of light pollution in and around Kirkville, Missouri and around Anderson Mesa near Flagstaff, Arizona. We quantify the amount of light that is projected up towards the sky, instead of the ground, using Unihedron sky quality meters installed at various locations. We also present results from DSLR photometry of several standard stars, and compare the photometric quality of the data collected at locations with varying levels of light pollution. Presently, light fixture
shields and ‘warm-colored’ lights are being installed on Truman State University’s campus in order to reduce light pollution. We discuss the experimental procedure we use to test the effectiveness of the different light fixtures shields in a controlled setting inside the Del and Norma Robison Planetarium. Apart from negatively affecting the quality of the night sky for astronomers, light pollution adversely affects migratory patterns of some animals and sleep-patterns in humans, increases our carbon footprint, and wastes resources and money. This problem threatens to get particularly acute with the increasing use of outdoor LED lamps. We conclude with a call to action to all professional and amateur astronomers to act against the growing nuisance of light pollution.

Author(s): Vayujeet Gokhale, David Caples, Jordan Goin, Ashley Herdman, Steven Pankey, Emily Wren
Institution(s): 1. MACC, 2. Truman State University

223.04 – The Complete Calibration of the Color-Redshift Relation (C3R2) survey for Euclid

The complete calibration of the color-redshift relation (C3R2) survey is a multi-institution, multi-instrument survey with the Keck telescopes that aims to map out the empirical galaxy color-redshift relation in preparation for the Stage IV dark energy missions Euclid and WFIRST. A key challenge for weak lensing cosmology with these missions will be measuring highly accurate redshift distributions for billions of faint galaxies using only broad-band photometric observations. Well-calibrated photometric redshifts will thus be critical to their success. C3R2 uses an innovative technique that maps the color distribution of galaxies in the high-dimensional color space (u-g, g-r, r-i, i-z, J-H) expected for Euclid and WFIRST, allowing us to focus spectroscopic effort on those regions of galaxy color space which are currently unexplored. C3R2 is a joint effort involving all of the Keck partners, with 44.5 nights allocated thus far. DR1 is published (Masters, Stern, Cohen et al, ApJ, 841, 111), and DR2, with > 3000 new redshifts, will be submitted in mid 2018.

Author(s): Judith Cohen, Daniel Masters
Institution(s): 1. Caltech, 2. Jet Propulsion Laboratory
Contributing team(s): the C3R2 Team

223.05 – Identifying and Analyzing Preferences for the Next Decade of Astrophysics

The Decadal Survey is conducted by the United States National Academies and is a summary of opinions from individuals in the Astronomy community, used to recommend the next decade of prioritized astrophysics missions and activities. From a systems engineering and psychology perspective, the Decadal Survey process is interesting due to the large and diverse community being sampled, the diverse preferences, and the group interactions that result in a common voice. When preparing input to be reviewed in such a process, it is important to recognize and understand both individual factors, as well as group factors. By understanding these dynamics it is possible to better predict the likely outcome.

This research looks to better understand the preferences of the Astronomy community as they relate to the coming decade. Preferences are the desires held by an individual. Along with beliefs and alternatives, preferences are one of three necessary elements to make a decision, according to normative decision analysis. Hence, by understanding preferences, and making assumptions on beliefs and available alternatives, one can determine what decision an individual ought to make through normative decision analysis. Due to the community focus of the Decadal Study, it is important to understand the interactions of individuals that results in a group outcome. This is where game theory is an effective tool, enabling the mathematical analysis of interacting individuals.

Before any analysis is performed preferences must be captured and mathematically represented through value models, which is precisely what this research examines. This Iposter is associated with a questionnaire to better understand the preferences of individuals. The questionnaire will be promoted through the Iposter as well as by the authors at the conference. The questionnaire will attempt to gather data to enable the formation of value functions resulting in a better understanding of the community likings. The research is applicable to a wide range of similar community-driven recommendations, such as NSF proposal reviews.

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Institution(s): 1. University of Alabama in Huntsville

223.06 – APASS Data Release 10

The AAVSO Photometric All-Sky Survey (APASS) has been underway since 2010. This survey covers the entire sky from 7.5 < V < 16.5 magnitude, and in the BVugrizY bandpasses. A northern and a southern site are used, each with twin ASA 20cm astrographs and Apogee Aspen CG16m cameras, covering 2.9x2.9 square degrees with 2.6arcsec pixels. Landolt and SDSS standards are used for all-sky solutions, with typical 0.02mag calibration errors on the bright end. DR9 is currently available through VizieR. DR10 is a complete reprocessing of all 500K images taken with the system, including hundreds of nights not part of DR9. Sextractor is used for star finding and centroiding; DAOPHOT is used for aperture photometry; the astrometry.net plate-solving library is used for basic astrometry, supplemented with more precise WCS that utilizes knowledge of the optical train distortions. With these changes, DR10 includes many more stars than prior releases. We describe the survey, its remaining limitations, and prospects for the future, including a very-bright-star extension.

Author(s): Arne A. Henden, Stephen Levine, Dirk Terrell, Douglas L. Welch, Ulisse Munari, Brian K. Kloppenborg
Institution(s): 1. AAVSO, 2. Lowell Observatory, 3. McMaster University, 4. Pratum Labs, 5. Southwest Research Institute, 6. University of Padua

223.07 – A New Technique for Precision Photometry Using Alt/Az Telescopes

We present and test a new method for flat field calibration of images obtained on telescopes with altitude-azimuth (Alt-Az) mounts. Telescopes using Alt-Az mounts typically employ a field “de-rotator” to account for changing parallactic angles of targets observed across the sky, or for long exposures of a single target. This “de-rotation” results in a changing orientation of the telescope optics with respect to the camera. This, in turn, can result in a flat field that is a function of camera orientation due to, for example, vignetting. In order to account for these changes we develop and test a new flat field technique using the observations of known transiting exoplanets.

Author(s): Colin Kirkaptrick, Piper Stacey, Jonathan Swift
Institution(s): 1. PlaneWave Instruments

223.08 – Assessing Ozone Detectability on Weakly Oxygenated Terrestrial Exoplanets

Space-based telescope mission concepts currently under development by NASA would be capable of directly imaging exoplanets within the habitable zones of their host stars. The spectroscopic data from such missions could provide an opportunity to detect biosignatures. The strongest remotely detectable signature of life on our planet today is the photosynthetically produced oxygen (O2) in our atmosphere. However, recent studies of Earth’s geochemical proxy record suggest that for all but the last ~500 million years, atmospheric O2 would have been undetectable to a remote observer, a potential false negative for life. During an extended period in Earth’s middle history (2.0 – 0.7 billion years ago, Ga), O2 was likely present but in low concentrations, with pO2 estimates of ~0.1 – 1% of present-day levels. Recent biogeochemical modeling results have suggested methane (CH4) was likewise undetectably low during this period. Although O2 has a weak spectral impact in reflected light at abundances consistent with Earth’s middle...
history, O$_3$ in photochemical equilibrium with that O$_2$ would produce notable spectral features in the UV Hartley-Higgins band (\sim 0.25 \mu m), with a weaker impact in the mid-IR band near 9.7 \mu m. Thus, taking Earth history as an informative example, there likely exists a category of exoplanets for which conventional biosignatures can only be identified in the UV. We use simulated observations to emphasize the importance of UV capabilities in the design of future space-based direct imaging telescopes such as HabEx or LUVOIR to detect O$_3$ on planets with weakly oxygenated states. We also show that under low-O$_2$ conditions, seasonal variations in O$_2$ production and consumption by the biosphere could manifest as time-variable O$_3$. Such seasonality in the Hartley-Higgins band provides both an opportunity and a challenge for remote life–detection studies because this biosignature may only be detectable intermittently over a planet’s orbital period. These examples highlight the importance of UV capability for future direct-imaging telescopes and illustrate the broad implications of studying Earth history as a window into understanding potential exoplanet biosignatures.

**Author(s):** Edward Schwieterman$^2$, Stephanie Olson$^2$, Christopher Reinhard$^1$, Andy Riddle$^2$, Stephen R. Kane$^2$, Victoria Meadows$^3$, Timothy Lyons$^2$

**Institution(s):** 1. Georgia Institute of Technology, 2. University of California, Riverside, 3. University of Washington

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**300.09 – StarNet: An application of deep learning in the analysis of stellar spectra**

In an era when spectroscopic surveys are capable of collecting spectra for hundreds of thousands of stars, fast and efficient analysis methods are required to maximize scientific impact. These surveys provide a homogeneous database of stellar spectra that are ideal for machine learning applications. In this poster, we present StarNet: a convolutional neural network model applied to the analysis of both SDSS-III APOGEE DR13 and synthetic stellar spectra. When trained on synthetic spectra alone, the calculated stellar parameters (temperature, surface gravity, and metallicity) are of excellent precision and accuracy for both APOGEE data and synthetic data, over a wide range of signal-to-noise ratios. While StarNet was developed using the APOGEE observed spectra and corresponding ASSET synthetic grid, we suggest that this technique is applicable to other spectral resolutions, spectral surveys, and wavelength regimes. As a demonstration of this, we present a StarNet model trained on lower resolution, R=6000, IR synthetic spectra, describing the spectra delivered by Gemini/NIFS and the forthcoming Gemini/GIRMOS instrument (PI Sivanandam, UToronto). Preliminary results suggest that the stellar parameters determined from this low resolution StarNet model are comparable in precision to the high-resolution APOGEE results. The success of StarNet at lower resolution can be attributed to (1) a large training set of synthetic spectra (N \sim 200,000) with a priori stellar labels, and (2) the use of the entire spectrum in the solution rather than a few weighted windows, which are common methods in other spectral analysis tools (e.g. FERRE or The Cannon). Remaining challenges in our StarNet applications include rectification, continuum normalization, and wavelength coverage. Solutions to these problems could be used to guide decisions made in the development of future spectrographs, spectroscopic surveys, and data reduction pipelines, such as for the future MSE.

**Author(s):** Collin Kielt$^2$, Spencer Bialek$^2$, Sebastien Fabbro$^1$, Kim Venn$^2$, Teaghan O’Brien$^2$, Farbod Jahandar$^2$, Stephanie Monty$^2$

**Institution(s):** 1. National Research Council Herzberg Astronomy & Astrophysics, 2. University of Victoria

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**300 – George Ellery Hale Prize Talk: Amazing Journeys to the Hearts of Stars, Sarbani Basu (Yale University)**

In his seminal book on the structure of stars, Arthur Eddington had mourned that we will never be able to peer into the opaque layers of a star and see what is within. Little did he know that in less than 50 years we would find the means of doing just that by using seismic data of the Sun and other stars.

In this talk I will share with you some of the results obtained through seismic studies of stars. I will begin with the story of helioseismology and the surprising results that we have obtained for the Sun. And next I will go on to other stars and what we have learned using data obtained by the Kepler mission and how discuss how these data are being used to study the structure and evolution of the Galaxy.

**Author(s):** Sarbani Basu$^1$

**Institution(s):** 1. Yale University

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**301 – Decadal Survey Preparations: State of the Profession**

The 2000 and 2010 Astronomy and Astrophysics Decadal Survey Reports included chapters on ‘The State of the Profession’. In these chapters are recommendations and findings that acknowledge concerns for the future of the astronomical workforce and have lead to actions to promote career direction initiatives by the federal agencies, for example, the inauguration of the NSF’s Astronomy and Astrophysics Postdoctoral Fellowship. Over the past 3 years, there have been a number of meetings and workshops with a focus on the strengthening the astronomical workforce and promoting improved workplace climate. Groups and individuals involved in these meeting have produced draft white papers to be submitted to the 2020 Decadal Survey panel members that will contribute to the next ‘The State of the Profession’ chapter. In this session, members of the community leading white papers and other advisory efforts will have the opportunity to present their activities to the larger community, build collaborations on topics of interest and solicit additional signatories to their efforts.

**301.01 – Progress on white papers from the Demographic Hack Session at WiA IV**

At the Women in Astronomy IV meeting in June 2017, a number of white papers were started as part of the Demographic Hack session. Several of these white papers are intended for submission to the Decadal Survey on topics including, ‘Providing a Timely Review of Input Demographics to Advisory Committees’, and ‘Tying Research Funding to Progress in Inclusion’. In my talk, I will review the content of these white papers and the progress that has been made in writing them. Interested session attendees are encouraged ‘endorse’ the papers by becoming signatories.

**Author(s):** Dara J. Norman$^1$

**Institution(s):** 1. NOAO

**Contributing team(s):** WiA IV Demographics Hack Session Attendees

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**301.02 – White Papers Emerging from Women in Astronomy IV**

During the Women in Astronomy IV meeting in Austin, TX, in June, 2017, planning workshops were held for several white papers. This talk will present those papers’ main points and/or introduce the papers’ lead authors to make those presentations. Each paper’s lead authors, its title, and a brief summary follow.

Nancy Morrison and Van Dixon, "Graduate Admissions in a Post-GRE World": Research has shown that the use of a hard cutoff in GRE scores results in lack of ethnic and gender diversity in admitted cohorts. In addition, GRE scores are not well correlated with various measures of success in graduate school and beyond.
Alternative admission metrics, including non-cognitive assessments, are explored. This talk will complement the related presentation to be given by A. Rudolph.

Lia Corrales, "Inclusion and Access in Teaching and Training": equitable administration of university teaching, including hiring and evaluation of instruction; best practices for ensuring that all students are included in classroom learning; improvements in training of teachers and group leaders; and inclusivity in research groups and institutions.

Sarah Tuttle and Aparna Venkatesan, "Benefits & Rights Policy": best practices for institutions to support people with disabilities in terms of universal design and to support families in terms of family and dependent care leave policies and health insurance. Venkatesan will speak about "Building an Inclusive Workplace."

Dara Norman, "Demographics": Demographic surveys need to include intersectionality among not only personal demographics, (such as race, gender, sexual orientation, etc.) but also workforce demographics (such as area of research and career status). This information is essential for an understanding of specific processes affecting underrepresented groups in astronomy. Norman will address this and related topics separately.

Author(s): Nancy D. Morrison1
Institution(s): 1. University of Toledo
Contributing team(s): Women in Astronomy IV Organizing Committee and conference attendees

301.03 – Developing a diverse and inclusive workforce in astronomy

Workforce development -- the preparation and advancement of a diverse and effective workforce -- in astronomy demands attention to a range of different career pathways, such as scientific users, telescope operations, and instrument builders. We will discuss the resources, expertise, and leadership needed to address workforce development challenges in astronomy, and the potential of one or more white papers to be prepared for the 2020 Decadal Survey. Potential white paper topics include (1) mentoring, training, and workplace practices to support diversity and inclusion; (2) enabling the next generation of astronomy faculty to teach effectively and inclusively; (3) supporting telescopes’ needs for local engineering and technologist talent, while telescope collaborations grow in scale and global extent; and (4) equipping early-career astronomers and instrumentalists with strategies and tools that are necessary for collaborating effectively on international teams.

Author(s): Lisa Hunter2, Nicholas McConnell2, Scott Seagroves2, Austin Barnes2, Sonya Smith1, Rafael Palomino2
Institution(s): 1. Howard University, 2. University of California, Santa Cruz

301.04 – Recommendations from Inclusive Astronomy: Position Papers for The Decadal Survey

302 – Preparing for JWST Science with the Early Release Science Programs: Astrochemistry and the ISM

The Director’s Discretionary Early Release Science (DD-ERS) program was designed to educate and inform the community regarding JWST’s capabilities, and provide rapid access to substantive, representative datasets to enable full scientific exploitation in Cycle 2 and beyond. The 13 selected programs were announced in November 2017, and the teams have already gotten to work on products to fulfill the mission of the DD-ERS. In this session, team members of DD-ERS programs observing astrochemistry in disks and the ISM will give an overview of their planned observations and the science-enabling products they are working on for the community. We will allow time for discussion with the teams.

302.01 – JWST DD ERS Team Update: Decoding Smoke Signals from WR140 using NIRISS+AMi and MIRI/MRS

Dust is a key component of the interstellar medium and plays and important role in the formation of stars and planets. However, the dominant channels of dust production throughout cosmic time are uncertain. With its unprecedented sensitivity and spatial resolution in the mid-IR, the James Webb Space Telescope
(JWST) is the ideal platform to address this issue by investigating the dust abundance, composition, and production rates of various dusty sources. In particular, colliding-wind Wolf-Rayet (WR) binaries are known to be efficient dust producers in the local Universe and likely existed in the earliest galaxies. In our Early Release Science (ERS) program, we will use JWST to observe the archetypal colliding-wind binary, WR 140, to study its dust composition, abundance, and formation mechanisms. We will utilize two key JWST observing modes with the medium-resolution spectrometer (MRS) on the Mid-Infrared Instrument (MIRI) and the Aperture Masking Interferometry (AMI) mode with the Near Infrared Imager and Slitless Spectrograph (NIRISS). Our planned observations will establish a benchmark for key observing modes for imaging bright sources with faint extended emission at high spatial resolutions. This will be valuable in various astrophysical contexts including mass-loss from evolved stars, dusty tori around active galactic nuclei, and protoplanetary disks. We are committed to delivering science-enabling products for the JWST community that include high-level pipeline tools to mitigate bright source artifacts and image reconstruction tools compatible with NIRISS+AMI data.

**Author(s): Ryan M. Lau¹, Matt Hankins²**

**Institution(s): 1. California Institute of Technology, 2. Cornell University**

**Contributing team(s):** WR DustERS Team

### 302.02 – Radiative Feedback from Massive Stars as Traced by Multiband Imaging and Spectroscopic Mosaics

Massive stars disrupt their natal molecular cloud material by dissociating molecules, ionizing atoms and molecules, and heating the gas and dust. These processes drive the evolution of interstellar matter in our Galaxy and throughout the Universe from the era of vigorous star formation at redshifts of 1-3, to the present day. Much of this interaction occurs in Photo-Dissociation Regions (PDRs) where far-ultraviolet photons of these stars create a largely neutral, but warm region of gas and dust. PDR emission dominates the IR spectra of star-forming galaxies and also provides a unique tool to study in detail the physical and chemical processes that are relevant for inter- and circumstellar media including diffuse clouds, molecular cloud and protoplanetary disk surfaces, globules, planetary nebulae, and starburst galaxies.

We propose to provide template datasets designed to identify key PDR characteristics in the full 1-28 µm JWST spectra in order to guide the preparation of Cycle 2 proposals on star-forming regions in our Galaxy and beyond. We plan to obtain the first spatially resolved, high spectral resolution IR observations of a PDR using NIRCam, NIRSpec and MIRI. We will observe a nearby PDR with well-defined UV illumination in a typical massive star-forming region. JWST observations will, for the first time, spatially resolve and perform a tomography of the PDR, revealing the individual IR spectral signatures from the key zones and sub-regions within the ionized gas, the PDR and the molecular cloud. These data will test widely used theoretical models and extend them into the JWST era. We will assist the community interested in JWST observations of PDRs through several science-enabling products (maps of spectral features, template spectra, calibration of narrow/broad band filters in gas lines and PAH bands, data-interpretation tools e.g. to infer gas physical conditions or PAH and dust characteristics). This project is supported by a large international team of one hundred scientists collaborators.

**Author(s): Alexander Tielens¹**

**Institution(s):** 1. Leiden Observatory

**Contributing team(s):** on behalf of the "PDRs4ever" team

### 302.03 – The IceAge ERS Program: Probing Building blocks of Life During the JWST Era

Icy grain mantles are the main reservoir for volatile elements in star-forming regions across the Universe, as well as the formation sites of pre-biotic complex organic molecules (COMs) seen in our Solar System. Through the IceAge Early Release Science program, we will trace the evolution of pristine and complex ice chemistry in a representative low-mass star-forming region through observations of: a) pre-stellar core, Class 0 protostar, Class I protostar, and protoplanetary disk. Comparing high spectral resolution (R=1500-3000) and sensitivity (S/N=100-300) observations from 3 to 15 micron to template spectra, we will map the spatial distribution of ices down to ~20-50 AU in these targets to identify when, and at what visual extinction, the formation of each ice species begins. Such high-resolution spectra will allow us to search for new COMs, as well as distinguish between different ice morphologies, thermal histories, and mixing environments.

The analysis of these data will result in science products beneficial to Cycle 2 proposers. A newly updated public laboratory ice database will provide feature identifications for all of the expected ices, while a chemical model fit to the observed ice abundances will be released publicly as a grid, with varied metallicity and UV fields to simulate other environments. We will create improved algorithms to extract NIRCAM WFI SS spectra in crowded fields with extended sources as well as optimize the defining of MIRI LRS spectra in order to recover broad spectral features. We anticipate that these resources will be particularly useful for astrochemistry and spectroscopy of fainter, extended targets like star forming regions of the SMC/LMC or more distant galaxies.

**Author(s): Melissa K. McClure¹4, Adwin Boogert¹6, Harold Linnartz², Tracy L. Beck³¹0, Ewine van Dishoeck⁴, Eiichi Eagi⁵, Robin Garrod¹⁸, Karl D. Gordon¹⁰, Maria Elisabetta Palumbo³³, Wendy Brown¹⁷, Helen Fraser¹¹, Sergio Ioppolo⁰⁸, Izaskun Jimenez-Serra⁸, Martin McCoustra⁴, Jennifer Noble¹₂, Yumi J. Pendleton⁶, Klaus Pontoppidan¹⁰, Serena Viti⁵, Jean E. Chiar⁹, Paola Caselli⁵, John Ira Bailey⁴, Jes Jorgensen⁷, Lars Kristensen⁷, Nadia Murillo⁴, Karin L. Oberg⁵².


**Contributing team(s):** IceAge ERS Team collaborators

### 303 – Low Radio Frequency Observations from Space: The Magnetospheres and Space Weather Environments of Extrasolar Planets

Magnetic fields play a fundamental role in the formation, evolution and ongoing physical characteristics of both stars and planets. The barrage of high-energy particles and magnetic field flux originating from the Sun during a large coronal mass ejection (CME) and the consequent display of aurorae at Earth’s magnetic poles are good examples of stellar and planetary magnetic activity, their intertwined relationship and the potential impact on planetary biospheres of such highly variable space weather. In-situ measurements by the MAVEN mission to Mars revealed the long-term impact of such activity, demonstrating that ion loss due to solar CMEs early in Mars history likely severely depleted its atmosphere. Fully understanding the implications of space weather for the young solar system, as well as the wider population of planet-hosting stars, requires remote sensing of this nature of phenomena in other stellar systems. As is the case for the Sun, stellar CMEs can be accompanied by bright radio bursts at low frequencies (typically <100 MHz in the Solar case), that are produced as the resulting shockwave propagates through the corona and interplanetary medium. Similarly, exoplanets that encounter such CMEs can increase in radio luminosity by orders

**Author(s): E. Chiar¹, Yvonne J. Pendleton¹, Izaskun Palumbo³³, Robin Garrod¹⁸, Karl D. Gordon¹⁰, Maria Elisabetta Palumbo³³, Wendy Brown¹⁷, Helen Fraser¹¹, Sergio Ioppolo⁰⁸, Izaskun Jimenez-Serra⁸, Martin McCoustra⁴, Jennifer Noble¹₂, Yumi J. Pendleton⁶, Klaus Pontoppidan¹⁰, Serena Viti⁵, Jean E. Chiar⁹, Paola Caselli⁵, John Ira Bailey⁴, Jes Jorgensen⁷, Lars Kristensen⁷, Nadia Murillo⁴, Karin L. Oberg⁵².


**Contributing team(s):** IceAge ERS Team collaborators
of magnitude at kHz-MHz frequencies. The latter is particularly significant, as a detection of this radio emission allows the direct measurement of the magnetic field strength of the planet, informing on whether the atmosphere of the planet can survive the intense magnetic activity of its host star. This session explores the motivation for searching for low frequency radio emission from stars and planets, summarizes current ground-based efforts to detect such activity and outlines the role of future space-based experiments in redefining planetary habitability.

**303.01 – The Prospect for Detecting Stellar Coronal Mass Ejections**

The astrophysical study of mass loss, both steady-state and transient, on the cool half of the HR diagram has implications both for the star itself and the conditions created around the star that can be hospitable or inimical to supporting life. Recent results from exoplanet studies show that planets around M dwarfs are exceedingly common, which together with the commonality of M dwarfs in our galaxy make this the dominant mode of star and planet configurations. The closeness of the exoplanets to the parent M star motivate a comprehensive understanding of habitability for these systems. Radio observations provide the most clear signature of accelerated particles and shocks in stars arising as the result of MHD processes in the stellar outer atmosphere. Stellar coronal mass ejections have not been conclusively detected, despite the ubiquity with which their radiative counterparts in an eruptive event (stellar flares) have. I will review some of the different observational methods which have been used and possibly could be used in the future in the stellar case, emphasizing some of the difficulties inherent in such attempts. I will provide a framework for interpreting potential transient stellar mass loss in light of the properties of flares known to occur on magnetically active stars. This uses a physically motivated way to connect the properties of flares and coronal mass ejections and provides a testable hypothesis for observing or constraining transient stellar mass loss. I will describe recent results using radio observations to detect stellar coronal mass ejections, and what those results imply about transient stellar mass loss. I will provide some motivation for what could be learned in this topic from space-based low frequency radio experiments.

**Author(s): Rachel A. Osten**, Michael Kevin Crosley

**Institution(s):** Johns Hopkins University, Space Telescope Science Institute

**303.02 – Magnetic Fields of Extrasolar Planets: Planetary Interiors and Habitation**

Ground-based observations showed that Jupiter’s radio emission is linked to its planetary-scale magnetic field, and subsequent spacecraft observations have shown that most planets, and some moons, have or had a global magnetic field. Generated by internal dynamos, magnetic fields are one of the few remote sensing means of constraining the properties of planetary interiors. For the Earth, its magnetic field has been speculated to be partially responsible for its habitability, and knowledge of an extrasolar planet’s magnetic field may be necessary to assess its habitability. The radio emission from Jupiter and other solar system planets is produced by an electron cyclotron maser, and detections of extrasolar planetary electron cyclotron masers will enable measurements of extrasolar planetary magnetic fields. Based on experience from the solar system, such observations will almost certainly require space-based observations, but they will also be guided by on-going and near-future ground-based observations.

This work has benefited from the discussion and participants of the W. M. Keck Institute of Space Studies "Planetary Magnetic Fields: Planetary Interiors and Habitability" and content within a white paper submitted to the National Academy of Science Committee on Exoplanet Science Strategy. 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.
304 – LAD: Bridging Laboratory & Astrophysics: Mega-Lab Studies of Astro-micro-physics

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on laboratory astrophysics studies at large user facilities.

304.01 – Laboratory X-ray Studies with Trapped Highly Charged Ions Using Synchrotrons and Free-electron Lasers

Laboratory studies on highly charged ions (HCI) using electron beam ion traps (EBITs) can cover all charge states and chemical elements found in astrophysical sources. Since their introduction in 1986, a wealth of emission measurements from the optical to the x-ray range have been carried out by different groups. In most of the work, electron-impact excitation was the driving mechanism, and high resolution spectrometers were used for the diagnostic of the emitted radiation. Other recent studies included x-ray emission following charge exchange, a mechanism which is present in many astrophysical environments and can help explain some of the unknown spectral features at 3.55 keV.

In the last decade, excitation and photoionization have also been investigated by exposing HCI trapped in an EBIT to intense, monochromatic radiation from free-electron lasers and synchrotron sources. Here, advanced monochromators in powerful undulator beamlines allowed us to work at photon energies from 50 eV to 15 keV while resolving the natural linewidths of x-ray transitions like the Kα complex of Fe up to the highest charge states, and to measure the oscillator strengths of, e.g., the neonlike Fe16+ spectrum. Photoionization studies have been performed for those species as well. Very recently, our novel compact EBIT with an off-axis electron gun allows for simultaneously using the photon beam downstream, enabling exact wavelength determinations referenced to HCI with accurately calculable transitions. We have performed a recalibration of the molecular and atomic oxygen soft x-ray absorption lines in the 500 eV range with an uncertainty estimate of 30 meV. This revealed a 600 meV calibration error that propagated through the literature for decades with the consequence of a 200 km/s misfit of the velocity in interstellar oxygen absorbers. Other possibilities for the compact EBIT are investigations of resonant photorecombination processes with excellent energy resolution. With the miniaturization of EBITs, laboratory astrophysics in the spectral domain of Chandra, XMM-Newton and the future Athena mission will be extremely simplified, enabling atomic and plasma physics studies and much-improved instrumental calibrations.

Author(s): José R. Crespo López-Urrutia
Institution(s): 1. Max-Planck-Institut fuer Kernphysik

304.02 – Rare Isotopes in the Multimessenger Era

While these isotopes only exist for fractions of seconds, their properties shape the resulting cosmic distribution of elements and the astronomical observables including spectra, neutrinos, and gravitational waves. The long standing challenge in nuclear astrophysics of the production of the relevant isotopes in the laboratory is now overcome with a new generation of rare isotope accelerator facilities now coming online. One example is the FRIB facility under construction at Michigan State University for the US Department of Energy, Office of Science, Office of Nuclear Physics. These new capabilities in nuclear physics coincide with advances in astronomy directly related to the cosmic sites where these isotopes are created, in particular in time domain and gravitational wave astronomy. I will discuss the importance of rare isotope physics in interpreting multi-messenger observations and how advances in nuclear physics and astronomy when combined promise to lead us towards a comprehensive theory of the origin of the elements.

Author(s): Hector deWane1, Mark C. McCarthy2, Michael C. McCarthy1, Phillip C. Stancil3, DeWayne Halfen2, Mark Burton2, Carl A. Gottlieb1, Kelvin Lee1
Institution(s): 1. Michigan State University

304.03 – Laboratory Rotational Spectroscopy in the Era of ALMA: Applications to Disks and Circumstellar Outflows

The enormous leap in sensitivity and angular resolution offered by the Atacama Large Millimeter Array (ALMA) has revealed the presence of ever greater chemical complexity in astronomical sources, with an increasing number of unidentified lines. The need for supporting laboratory spectroscopy has become more urgent to fully exploit the scientific impact of ALMA. Rotational transition measurements are particularly important in this regard, as are the evaluation of line strengths, collisional cross sections, and dipole moments. Here we present new spectroscopic data concerning a wide range of potential interstellar and circumstellar molecules, including silicon and metal-bearing species, lines arising from vibrationally-excited molecules, and supporting theoretical calculations. Recent work concerning AlC2, KO, and vibrationally-excited AlO will be presented.

Author(s): Hendrik Schatz1
Institution(s): 1. Michigan State University

304.04 – Fluorescent Fe K Emission from High Density Accretion Disks

Iron K-shell lines emitted by gas closely orbiting black holes are observed to be grossly broadened and skewed by Doppler effects and gravitational redshift. Accordingly, models for line profiles are widely used to measure the spin (i.e., the angular momentum) of astrophysical black holes. The accuracy of these spin estimates is called into question because fitting the data requires very high iron abundances, several times the solar value. Meanwhile, no plausible physical explanation has been proffered for why these black hole systems should be so iron rich. The most likely explanation for the super-solar iron abundances is a deficiency in the models, and the leading candidate cause is that current models are inapplicable at densities above $10^{18}$ cm$^{-3}$. We study the effects of high densities on the atomic parameters and on the spectral models for iron ions. At high densities, Debye plasma can affect the effective atomic potential of the ions, leading to observable changes in energy levels and atomic rates with respect to the low density case. High densities also have the effect of lowering energy the atomic continuum and reducing the recombination rate coefficients. On the spectral modeling side, high densities drive level populations toward a Boltzmann distribution and very large numbers of excited atomic levels, typically accounted for in theoretical spectral models, may contribute to the K-shell spectrum.
305 – Stellar Abundances in Dwarf Galaxies

305.01 – Chemical Evolution and the Formation of Dwarf Galaxies in the Early Universe

Stellar abundances in local dwarf galaxies offer a unique window into the nature and nucleosynthesis of the first stars. They also contain clues regarding how galaxies formed and assembled in the early stages of the universe. In this talk, I will present our effort to connect nuclear astrophysics with the field of galaxy formation in order to define what can be learned about galaxy evolution using stellar abundances. In particular, I will describe the current state of our numerical chemical evolution pipeline which accounts for the mass assembly history of galaxies, present how we use high-redshift cosmological hydrodynamic simulations to calibrate our models and to learn about the formation of dwarf galaxies, and address the challenge of identifying the dominant r-process site(s) using stellar abundances.

Author(s): Benoit Cote
Institution(s): 1. Michigan State University
Contributing team(s): JINA-CEE, NuGrid, ChETEC

305.02 – Dwarf galaxies: a lab to investigate the neutron capture elements production

In this contribution, I focus on the neutron capture elements observed in the spectra of old halo and ultra faint galaxies stars. Adopting a stochastic chemical evolution model and the Galactic halo as a benchmark, I present new constraints on the rate and time scales of r-process events, based on the discovery of the r-process rich stars in the ultra faint galaxy Reticulum 2. I also show that an s-process activated by rotation in massive stars can play an important role in the production of heavy elements.

Author(s): Gabriele Cescutti
Institution(s): 1. Trieste Observatory, INAF

305.03 – Feedback Driven Chemical Evolution in Simulations of Low Mass Dwarf Galaxies

Galaxy chemical properties place some of the best constraints on models of galaxy evolution. Both gas and stellar metal abundances in galaxies depend upon the integrated star formation history of the galaxy, gas accretion, outflows, and the effectiveness of metal mixing within the interstellar medium (ISM). Capturing the physics that governs these processes in detail, however, is challenging, in part due to the difficulty in self-consistently modelling stellar feedback physics that impacts each of these processes. Using high resolution hydrodynamics simulations of isolated dwarf galaxies where we follow stars as individual star particles, we examine the role of feedback in driving dwarf galaxy chemical evolution. This star-by-star method allows us to directly follow feedback from stellar winds from massive and AGB stars, stellar ionizing radiation and photoelectric heating, and supernovae. Additionally, we track 15 individual metal species yields from these stars as they pollute the ISM and enrich new stellar populations. I will present initial results from these simulations in the context of observational constraints on the retention/ejection of metals from Local Group dwarf galaxies. In addition, I will discuss the variations with which individual elements evolve in the various phases of the ISM, as they progress from hot, ionized gas down to cold, star forming regions. I will conclude by outlining the implications of these results on interpretations of observed chemical abundances in dwarf galaxies and on standard assumptions made in semi-analytic chemical evolution models of these galaxies.

Author(s): Andrew Emerick2, Greg Bryan2, Mordecai-Mark Mac Low1
Institution(s): 1. American Museum of Natural History, 2. Columbia University

305.04 – Stellar properties of dwarf galaxies and their connections with the Milky Way halo

In this talk, relying on recent chemo-dynamical simulations, I will describe the stellar properties and in particular the abundances ratios of dwarf galaxies emerging from a LCDM framework. Paint systems quenched by the UV-background as well as luminous ones exhibiting an extended star formation history nicely reproduce observations, without necessary requiring a strong interaction with the Milky Way. However, dwarf galaxies with complex star formation histories like Carina and Fornax are much more difficult to reproduce. Those systems are often believed to result from an interaction with the Milky Way. I will show that when such interaction is taken into account in our high resolution simulations through ram pressure stripping, a much more complex reality appears.

Author(s): Yves Revaz1
Institution(s): 1. EPFL
Contributing team(s): Pascale Jablonka

305.05 – Manganese in Dwarf Galaxies as a Probe of Type Ia Supernovae

Despite the importance of thermonuclear or Type Ia supernovae (SNe) as standard candles in astrophysics, the physical mechanisms behind Type Ia SNe are still poorly constrained. Theoretically, the nucleosynthetic yields from Type Ia SNe can distinguish among different models of Type Ia explosions. For example, neutron-rich elements such as manganese (Mn) are sensitive probes of the physics of Type Ia SNe because their abundances are correlated to the density of the progenitor white dwarf. Since dwarf galaxies' chemical evolution is dominated by Type Ia SNe at late times, Type Ia nucleosynthetic yields can be indirectly inferred from stellar abundances in dwarf galaxies. However, previous measurements of Mn in dwarf galaxies are too incomplete to draw definitive conclusions on the Type Ia explosion mechanism. In this work, we therefore use medium-resolution stellar spectroscopy from Keck/DEIMOS to measure Mn abundances in red giants in several Milky Way satellite galaxies. We report average Type Ia Mn yields computed from these abundances, and we discuss the implications for Type Ia supernova physics.

Author(s): Mithi De Los Reyes1, Evan N Kirby1
Institution(s): 1. California Institute of Technology

306 – Stellar Topics I

306.01 – Robo-AO M Dwarf Multiplicity Survey

We analyzed close to 7,000 observations from Robo-AO’s field M dwarf survey taken on the 2.1m Kitt Peak telescope. Results will help determine the total multiplicity fraction and multiplicity functions of M dwarfs, which are crucial steps towards understanding their evolution and formation mechanics. Through its robotic, laser-guided, and automated system, the Robo-AO instrument has yielded the largest adaptive-optics M dwarf survey to date. I developed a graphical user interface to quickly analyze this data. Initial data analysis included assessing data quality, checking the result from Robo-AO’s automatic reduction pipeline, and determining existence as well as the relative position of companions through a visual inspection. This program can be applied to other datasets and was successfully tested by re-analyzing observations from a separate Robo-AO survey. After a
306.02D – Long-Term Variability of the Sun in the Context of Solar-Analog Stars

The Sun is the best observed object in astrophysics, but despite this distinction the nature of its well-ordered generation of magnetic field in 11-year activity cycles remains a mystery. In this work, we place the solar cycle in a broader context by examining the long-term variability of solar analog stars within 5% of the solar effective temperature, but varied in rotation rate and metallicity. Emission in the Fraunhofer H & K line cores from singly-ionized calcium in the lower chromosphere is due to magnetic heating, and is a proven proxy for magnetic flux on the Sun. We use Ca H & K observations from the Mount Wilson Observatory HK project, the Lowell Observatory Solar Stellar Spectrograph, and other sources to construct composite activity time series of over 100 years in length for the Sun and up to 50 years for 26 nearby solar analogs. Archival Ca H & K observations of reflected sunlight from the Moon using the Mount Wilson instrument allow us to properly calibrate the solar time series to the S-index scale used in stellar studies. We find the mean solar S-index to be 5–9% lower than previously estimated, and the amplitude of activity to be small compared to active stars in our sample. A detailed look at the young solar analog HD 30495, which rotates 2.3 times faster than the Sun, reveals a large amplitude ~12-year activity cycle and an intermittent short-period variation of 1.7 years, comparable to the solar variability time scales despite its faster rotation. Finally, time series analyses of the solar analog ensemble and a quantitative analysis of results from the literature indicate that truly Sun-like cyclic variability is rare, and that the amplitude of activity over both long and short timescales is linearly proportional to the mean activity. We conclude that the physical conditions conducive to a quasi-periodic magnetic activity cycle like the Sun’s are rare in stars of approximately the solar mass, and that the proper conditions may be restricted to a relatively narrow range of rotation rates.

Author(s): Ricky Egeland
Institution(s): 1. National Center for Atmospheric Research

306.03 – The Role of Rotation in Convective Heat Transport: an Application to Low-Mass Stars

It is often supposed that the convection zones (CZs) of low-mass stars are purely adiabatically stratified. This is thought to be because convective motions are extremely efficient at homogenizing entropy within the CZ. For a purely adiabatic fluid layer, only very small temperature variations are required to drive convection, making the amplitude and overall character of the convection highly sensitive to the degree of adiabaticity established in the CZ. The presence of rotation, however, fundamentally changes the dynamics of the CZ; the strong downflow plumes that are required to homogenize entropy are unable to penetrate through the entire fluid layer if they are deflected too soon by the Coriolis force. This talk discusses 3D global models of spherical-shell convection subject to different rotation rates. The simulation results emphasize the possibility that for stars with a high enough rotation rate, large fractions of their CZs are not in fact adiabatically stratified; rather, there is a finite superadiabatic gradient that varies in magnitude with radius, being at a minimum in the CZ’s middle layers. Two consequences of the varying superadiabatic gradient are that the convective amplitudes at the largest length scales are effectively suppressed and that there is a strong latitudinal temperature gradient from a cold equator to a hot pole, which self-consistently drives a thermal wind. A connection is naturally drawn to the Sun’s CZ, which has supergranulation as an upper limit to its convective length scales and isorotational contours along radial lines, which can be explained by the presence of a thermal wind.

Author(s): Claire Lammle, Christoph Baranec, Zachary K. Berta-Thompson, Nicholas M. Law3, Carl Ziegler3, Jessica Schonhut-Staik

306.05 – A Search for Strong Radio Emission from the Magnetic Interactions of Trappist-1 and its Satellites

The first nearby very-low mass star planet-host discovered, Trappist-1, presents not only a unique opportunity for studying a system of multiple terrestrial planets, but a means to examine the possibility of significant star-planet magnetic interactions at the end of the main sequence. These very-low mass stars and brown dwarfs have been observationally confirmed as capable of generating strong radio emissions produced by the electron cyclotron maser instability as a consequence of currents coupling the magnetospheric environment to the stellar atmosphere. However, multiple electrodynamic mechanisms have been proposed to power these magnetospheric processes, including a potentially significant role for short-period satellites analogous to the auroral interactions between Jupiter and its moons or the Sun and the solar system planets. With multiple close in terrestrial satellites, the Trappist-1 system is an important test case of these potential theories. We present a search for these radio emissions from the seven-planet Trappist-1 system using the Karl G. Jansky Very Large Array, looking for both highly circularly polarized radio emission and persistent quiescent emissions at GHz frequencies. We place these observations in the context of the possible electrodynamic engines driving radio emissions in very-low mass stars and brown dwarfs, and their relation to magnetic field topology, with implications for future radio surveys of planet-hosts at the end of the main sequence.

Author(s): Marat Musin, Haojiao Yan
Institution(s): 1. University of Missouri-Columbia

307 – Plenary Talk: Supermassive Black Hole Fueling and Feedback in Galaxies, Julie Comerford (University of Colorado, Boulder)

307.01 – Supermassive Black Hole Fueling and
Feedback in Galaxies

Over the last few decades, observations have revealed surprisingly tight correlations between the properties of galaxies and their supermassive black holes. Active galactic nuclei (AGN) have emerged as key drivers of this coevolution of galaxies and supermassive black holes, by two primary mechanisms: AGN fueling and AGN feedback. Supermassive black holes build up mass by accreting gas during AGN fueling, while AGN feedback is a crucial regulator of star formation that controls the mass growth of the galaxies. In this talk, I will present multiwavelength studies of both AGN fueling and feedback. I will discuss results that address AGN fueling in galaxy mergers, the connection between AGN and star formation, and the effect of AGN outflows on their host galaxies.

Author(s): Julia M. Comerford
Institution(s): 1. University of Colorado, Boulder

310 – Contributions from NASA's Nancy Grace Roman Technology Fellows

The Nancy Grace Roman Technology Fellowship (RTF) is a highly competitive technology fellowship for early career, US astronomers and astrophysicists in academia, government and the private sector. The Fellowship, started in 2010, is designed to develop and mature the next generation of principal investigators for NASA’s science instruments and missions. The Fellowship is managed by The Astrophysics Division at NASA Headquarters. This special AAS session is designed to showcase the breadth and depth of RTF fellows’ work to the larger community, so as to help sustain and grow the community's interest and investment in the RTF, as NASA’s Astrophysics Division premier early-career program for astronomers and astrophysicists focusing on technology development.

310.01 – EDGES and the Development of Absolute Calibration for Wideband Radio Receivers for 21cm Cosmology

The ultra-violet light emitted by early stars, when the universe was less than 400 million years old, alters the excitation state of the 21cm hyperfine line of primordial neutral hydrogen gas that surrounds the stars. This causes the gas to absorb photons from the cosmic microwave background (CMB). Later, energy deposited into the gas by the ultra-violet and X-ray emission from these early stars and their remnants heats the gas and eventually ionizes it. These effects produce spectral features in the CMB observable today at frequencies redshifted to below 200 MHz. The 21cm signal is approximately 10,000 times fainter than the foreground synchrotron emission from the Milky Way, leading to the requirement that any instrument designed to observe it must have a knowable response at the 0.01% level. Typical radio receivers used in astronomical measurements are accurate at the 1-10% level. Over the last decade, our team has investigated new radio receiver designs and accurate calibration strategies in the laboratory and in ground-based instruments to achieve the 0.01% performance goal. Building on these efforts, we recently reported evidence for detection of the redshifted 21cm signal as a decrease in the sky-averaged radio intensity observed by the Experiment to Detect the Global EoR Signature (EDGES). We found a flattened absorption profile in the measured radio spectrum centered at a frequency of 78 MHz with full width at half maximum of 19 MHz and an amplitude of 0.5 K. The frequency of the profile is roughly consistent with astrophysical models of early star formation. However, the amplitude of the observed profile is more than a factor of two greater than the largest standard predictions and suggests that the gas was either significantly colder than expected or the background radiation temperature was hotter than expected.

Author(s): Judd D. Bowman
Institution(s): 1. Arizona State University

310.02 – Discovering the Highest Energy Neutrinos Using a Radio Phased Array

The detection of high energy neutrinos is an important step toward understanding the most energetic cosmic accelerators and would enable tests of fundamental physics at energy scales that cannot easily be achieved on Earth. IceCube has detected astrophysical neutrinos at lower energies, and at higher energies the best limits to date on the flux comes from IceCube and the ANITA experiment, a NASA balloon-borne radio telescope designed to detect coherent radio Cherenkov emission from cosmogenic ultra-high energy neutrinos. I will discuss a new radio phased array design that will push the achievable sensitivity and lower the energy threshold. I will discuss the initial deployment and performance of an 8-channel system in a ground-based experiment at the South Pole (ARA), and the plans for scaling to O(100) channels and lowering the power consumption for future balloon-borne and ground-based applications.

Author(s): Abigail Vieregg
Institution(s): 1. University of Chicago

310.03 – Development and flight testing of UV optimized Photon Counting CCDs

I will discuss the latest results from the Hamden UV/Vis Detector Lab and our ongoing work using a UV optimized EMCCD in flight. Our lab is currently testing efficiency and performance of delta-doped, anti-reflection coated EMCCDs, in collaboration with JPL. The lab has been set-up to test quantum efficiency, dark current, clock-induced-charge, and read noise. I will describe our improvements to our circuit boards for lower noise, updates from a new, more flexible NUVU controller, and the integration of an EMCCD in the FIREBall-2 UV spectrograph. I will also briefly describe future plans to conduct radiation testing on delta-doped EMCCDs (both warm, unbiased and cold, biased configurations) thus summer and longer term plans for testing newer photon counting CCDs as I move the HUVD Lab to the University of Arizona in the Fall of 2018.

Author(s): Erika T. Hamden
Institution(s): 1. California Institute of Technology

310.04 – Minerva-Red: Small Planets Orbiting Small Stars

Recent results from Kepler and ground-based exoplanet surveys suggest that low-mass stars are host to numerous small planets. Since low-mass stars are intrinsically faint at optical wavelengths, obtaining the Doppler precision necessary to detect these companions remains a challenge for existing instruments. I will describe MINERVA-Red, a project to use a robotic, near-infrared optimized 0.7-meter telescope and a specialized Doppler spectrometer to carry out an intensive, multi-year campaign designed to reveal the planetary systems orbiting some of the closest stars to the Sun. The MINERVA-Red cross-dispersed echelle spectrograph is optimized for the “deep red”, between 800 nm and 900 nm, where the stars that will be targeted are relatively bright. The instrument is very compact and designed for the ultimate in Doppler precision – it uses a single-mode fiber input. I will describe the spectrometer and the status of the MINERVA-Red project, which is expected to begin routine operations at Whipple Observatory on Mt Hopkins, Arizona, in 2018.

Author(s): Cullen Blake
Institution(s): 1. University of Pennsylvania

310.05 – Advanced Environmentally Resistant Lithium Fluoride for Next-Generation Broadband Observatories

Recent advances in the physical vapor deposition of protective fluoride films have raised the far ultraviolet (FUV: 912 – 1600 Ångström) reflectivity of aluminum-based mirrors closer to the theoretical limit. The greatest gains have come for lithium fluoride protected aluminum, which has the shortest wavelength
311 – Preparing for JWST Science with the Early Release Science Programs: Planets

The Director's Discretionary Early Release Science (DD-ERS) program was designed to educate and inform the community regarding JWST's capabilities, and provide rapid access to substantive, representative datasets to enable full scientific exploitation in Cycle 2 and beyond. The 13 selected programs were announced in November 2017, and the teams have already gotten to work on products to fulfill the mission of the DD-ERS. In this session, team members of DD-ERS programs observing planets, in our solar system and others, will give an overview of their planned observations and the science-enabling products they are working on for the community. We will allow time for discussion with the teams.

311.02 – Jovian System as a Demonstration of JWST's Capabilities for Solar System Science: Status Update

Characterize Jupiter's cloud layers, winds, composition, auroral activity, and temperature structure; Produce maps of the atmosphere and surface of volcanically-active Io and icy satellite Ganymede to constrain their thermal and atmospheric structure, and search for plumes; Characterize the ring structure, and its sources, sinks and evolution.

We will present our progress to date in planning these observations and provide an update on our expectations.

Our program will utilize all JWST instruments in different observing modes to demonstrate the capabilities of JWST's instruments on one of the largest and brightest sources in the Solar System and on very faint targets next to it. We will also observe weak emission/absorption bands on strong continua, and with NIRIS/AMI we will maximize the Strehl ratio on unresolved features, such as Io's volcanoes.

We will deliver a number of science enabling products that will facilitate community science, including, e.g.: i) characterizing Jupiter's scattered light in the context of scientific observations, ii) resolve point sources with AMI in a crowded field (Io's volcanoes), and compare this to classical observations, iii) develop tools to mosaic/visualize spectral datacubes using MIRI and NIRSpec on Jupiter. Finally, our program will also set a first temporal benchmark to study time variations in the jovian system and any interconnectivity (e.g., through its magnetic field) during JWST's lifetime.

Author(s): Al Conrad, Thierry Fouchet
Institution(s): 1. Observatoire de Paris, 2. W. M. Keck Observatory

312 – Low Radio Frequency Observations from Space: Redshifted 21-cm Hydrogen Cosmology from Space
Cosmic Dawn represents the last frontier in cosmology, the era of the formation of the first stars. A detectable signal at $v < 100$ MHz from the redshifted 21-cm line of neutral hydrogen surrounding the first luminous objects ($10 < z < 35$) is predicted from this epoch. The spectral nature of the 21-cm signal allows the evolution of the Universe as a function of redshift to be tracked. The Moon’s farside, on the surface or in orbit, is likely the best site in the inner solar system for these observations as it is free of human-generated interference and distortions caused by Earth’s ionosphere. New investigations are underway to explore key astrophysical processes driving the Cosmic Dawn 21-cm signal, to develop the technologies needed for suitable space-based instruments, and to demonstrate techniques that will maximize the extraction of astrophysical information about the first stars and galaxies from the low radio frequency signal.

312.01 – Shining Light into Cosmic Dark Ages
Exploration of the early Universe is ongoing. One of the most interesting probes of the epoch is the redshifted 21-cm line of neutral hydrogen. Modeling of this signal is difficult due to large uncertainties in both astrophysical and cosmological parameters that describe the high redshift Universe. In my talk I will discuss current theoretical understanding and the status of modeling.

Author(s): Anastasia Fialkov
Institution(s): 1. Harvard

312.02 – A Space-Based Observational Strategy for Hydrogen Cosmology Using Dynamic Polarimetry and Pattern Recognition
The redshifted 21-cm monopole is expected to be a powerful probe of the epoch of the first stars and galaxies ($10 < z < 80$). The global 21-cm signal is sensitive to the thermal and ionization state of hydrogen gas and thus provides a tracer of sources of energetic photons—primarily hot stars and accreting black holes—which ionize and heat the redshifted intergalactic medium. In this talk, we present a strategy for observations of the global spectrum with a satellite placed in low lunar orbit, performing night-time 10-50 MHz observations, while on the farside to avoid terrestrial radio frequency interference, ionospheric corruption, and solar radio emissions. The primary challenge is observing a relatively weak signal in the presence of a strong galactic/extragalactic foreground. We employ a new technique using dynamic or projection-induced polarimetry that separates the polarized foreground from the unpolarized 21-cm signal. Initial results from a ground-based prototype called the Cosmic Twilight Polarimeter will be described which tentatively reveal the presence of the expected polarization signature from the foreground. Dynamic polarimetry, when combined with sophisticated pattern recognition techniques based on training sets, machine learning, and statistical information criteria offer promise for precise extraction of the 21-cm spectrum. We describe a new SmallSat mission concept, the Dark Ages Polarimetry Pathfinder (DAPPer), that will utilize these novel approaches for extending the recent detection of a 78 MHz signal down to lower frequencies where we can uniquely probe evidence for the first stars and dark matter.

Author(s): Jack O. Burns3, Bang Nhan3, Richard F. Bradley2, Keith A. Tauscher2, David Rapetti3, Eric Switzer1

312.03 – Machine Learning and Experimental Design for Hydrogen Cosmology
Based on two powerful innovations, we present a new pipeline to analyze the redshifted sky-averaged 21-cm spectrum (10-200 MHz) of neutral hydrogen from the first stars, galaxies and black holes. First, we combine machine learning and model selection techniques to extract the global 21-cm signal from foreground and instrumental systematics. Second, we employ experimental designs to increase our ability to separate these two components in data sets. For measurements with foreground polarization induced by rotation about the anisotropic low-frequency radio sky on a large beam, we incorporate this information into the likelihood to distinguish the unpolarized 21-cm signal from the rest of the data. For experiments with a drift scan strategy, we take advantage of the varying foreground in time to identify the constant 21-cm signal. This pipeline can be applied to either lunar orbit/surface instruments shielded from terrestrial and solar radio contamination, or existing ground-based observations, such as those from the EDGES collaboration that recently observed an absorption trough potentially consistent with the global 21-cm signal of Cosmic Dawn. Finally, this pipeline allows us to constrain physical parameters for a given model of the first luminous objects plus exotic physics in the early universe, from e.g. dark matter, through an MCMC analysis that uses the extracted signal as a starting point, providing key efficiency for unexplored cosmologies.

Author(s): David Rapetti4, Keith A. Tauscher4, Jack O. Burns4, Jordan Mirocha3, Eric Switzer2, Raul A. Monsalve4, Steven R. Furlanetto3, Rudd D. Bowman1

312.04 – Design Optimization for Interferometric Space-Based 21-cm Power Spectrum Measurements
Observations of the highly-redshifted 21-cm hyperfine line of neutral hydrogen (HI) are one of the most promising probes for the future of cosmology. At redshifts $z > 30$, the HI signal is likely the only measurable emission, as luminous objects have yet to form. At these very low radio frequencies, however, the earth’s ionosphere becomes opaque — necessitating observations from space. The major challenge to neutral hydrogen cosmology (at all redshifts) lies in the presence of bright foreground emission, which can dominate the HI signal by as much as eight orders of magnitude at the highest redshifts. The only method for extracting the cosmological signal relies on the spectral smoothness of the foregrounds; since each frequency of the HI signal probes a different redshift, the cosmological emission is essentially uncorrelated from frequency to frequency. The key challenge for designing an experiment lies in maintaining the spectral smoothness of the foregrounds. If the frequency response of the instrument introduces spectral structure (or at least, a residual that cannot be calibrated out at the necessary precision), it quickly becomes impossible to distinguish the cosmological signal from the foregrounds. This principle has guided the design of ground-based experiments like the Precision Array for Probing the Epoch of Reionization (PAPER) and the Hydrogen Epoch of Reionization Array (HERA). However, there still exists no unifying framework for turning this design “philosophy” into a robust, quantitative set of performance metrics and specifications. In this talk, we present a strategy for observations of the global signal of Cosmic Dawn. Finally, this pipeline allows us to constrain physical parameters for a given model of the first stars and galaxies from the low radio frequency signal.

Author(s): Jonathan Pober1
Institution(s): 1. Brown University

312.05 – Toward a Cosmic Dawn Mapper
After stars formed in the early universe, their ultraviolet light altered the 21cm hyperfine state of hydrogen atoms, causing the atoms to absorb photons from the cosmic microwave background. The EDGES experiment has reported evidence for this signal as a decrease in the sky-averaged radio intensity observed today as a broad feature centered at 78 MHz due to cosmological redshift, corresponding to an age of about 200 million years after the Big Bang. Ground-based radio arrays are expected soon to detect and eventually to characterize the power spectrum of spatial fluctuations of the 21cm absorption signal. However, the Earth’s ionosphere and radio transmitters, particularly those in the FM radio band, will complicate the observations and likely will limit the ultimate goal of imaging the era of cosmic dawn in detail. A
radio array in lunar orbit or on the lunar surface would avoid the limitations imposed by Earth ionosphere’s. The Moon’s farside is also uniquely shielded from human-generated radio interference. Locating the radio observatory on the lunar surface compared to orbit has potential advantages, including fixed locations for the antennas that require no propulsion to maintain and simpler operations. The lunar surface poses unique challenges for instruments, including surviving the 14-day lunar night when there is no sunlight and temperatures can fall to 100 K. Building on lessons from ground based arrays and design studies from the last decade that led to the Dark Ages Lunar Interferometer and the Lunar Array for Radio Cosmology concepts, we are exploring a trade space for key lunar array technology. Our trade space includes choices related to: 1) antenna design for optimizing sensitivity and mass, while maintaining mechanical and thermal stability and enabling cost-effective deployment scenarios; 2) location of the array on the lunar surface to provide an efficient observing paradigm and suitable environmental conditions; 3) data transportation and processing for collecting antenna measurements at a central location for correlation and reduction; and 4) power and environmental requirements. In this talk, I will report the status of these ongoing studies.

Author(s): Judd D. Bowman
Institution(s): 1. Arizona State University

313 – LAD: Bridging Laboratory & Astrophysics: Cassini’s view on the Chemistry of the Saturn System

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the synergy of atmospheric modeling and laboratory studies to shape our understanding of chemistry in the Saturn System.

313.01 – Sarah Horst

313.02 – Modeling the Chemical Complexity in Titan’s Atmosphere

Titan’s atmospheric chemistry is extremely complicated because of the multiplicity of chemical as well as physical processes involved. Chemical processes begin with the dissociation and ionization of the most abundant species, N2 and CH4, by a variety of energy sources, i.e. solar UV and X-ray photons, suprathermal electrons (< keV) and ions (H+, O+, < MeV), and cosmic rays. The energetic species produced further react to generate a plethora of gaseous molecules that will eventually become organic aerosols. Thus, molecular growth is driven by gas phase reactions involving radicals as well as positive and negative ions, all possibly in some excited electronic and vibrational state. Heterogeneous chemistry at the surface of the aerosols could also play a significant role. The efficiency and outcome of these reactions depends strongly on the physical characteristics of the atmosphere, namely pressure and temperature, ranging from 1.5×103 to 10−10 mbar and from 70 to 200 K, respectively. Moreover, the distribution of the species is affected by molecular diffusion and winds as well as escape from the top of the atmosphere and condensation in the lower stratosphere.

Photochemical and microphysical models are the keystones of our understanding of Titan’s atmospheric chemistry. Their main objective is to compute the distribution and nature of minor chemical species (typically containing up to 6 carbon atoms) and haze particles, respectively. Density profiles are compared to the available observations, allowing to identify important processes and to highlight those that remain to be constrained in the laboratory, experimentally and/or theoretically. We argue that positive ion chemistry is at the origin of complex organic molecules, such as benzene, ammonia and hydrogen isocyanide while neutral-neutral radiative association reactions are a significant source of alkanes. We find that negatively charged macromolecules (m/z ~100) attract the abundant positive ions, which ultimately leads to the formation of the aerosols. We also discuss the possibility that an incoming flux of oxygen from Enceladus, another Saturn’s satellite, is responsible for the presence of oxygen-bearing species in Titan’s reductive environment.

Author(s): Veronique Vuitton3, Roger Yelle4, Stephen J. Klippenstein1, Sarah Horst2, Panayotis Lavvas5

313.03 – CIRS-Observed Titan’s Stratospheric Ice Clouds Studied in the Laboratory

Stratospheric ice clouds have been repeatedly observed in Titan’s atmosphere by the Cassini Composite InfraRed Spectrometer (CIRS) since the Cassini spacecraft entered into orbit around Saturn in 2004. Most of these stratospheric ice clouds form as a result of vapor condensation, composed of a combination of pure and mixed nitriles and hydrocarbons. So far, the crystalline cyanoacetylene (HC3N) v6 band at 506 cm−1 and a co-condensed nitrite ice feature at 160 cm−1, dominated by a mixture of HCN and HC3N ices, have been identified in the CIRS limb spectra. However, the presence of other observed stratospheric ice emission features, such as the v8 band of dicyanoacetylene (C4N2) at 478 cm−1 and the Haystack emission feature at 220 cm−1, are puzzling since they have no associated observed vapor emission features. As well, recently, a massive stratospheric ice cloud system, the High-Altitude South Polar (HASP) cloud, was discovered in Titan’s early southern winter stratosphere with an emission feature near 210 cm−1. We are investigating in laboratory these perplexing stratospheric ices to better understand their formation mechanisms, identify their chemical compositions, and determine their optical properties. We perform transmission spectroscopy of thin films of pure and mixed nitrile ices, as well as ices combined with hydrocarbons, from 50 cm−1 to 11700 cm−1, at deposition temperature 30 K - 150 K, using the SPECTRAL high-vacuum chamber at NASA GSFC. The spectral evolution with time and temperature is studied, the ice phase formation identified, and optical constants computed. The first surprising yet significant result reveals that the liberation mode of HCN is drastically altered by the surrounding molecules when mixing occurs in a co-condensed phase. For propionitrile ice, we observe peculiar temperature and time-driven ice phase transitions, revealed by significant spectral changes until a stable crystalline phase is achieved. Comparing our laboratory spectra to the CIRS data, we found that a HCN-C6H6 mixed ice is a good match for the HAP cloud emission feature. We present a summary of our laboratory results, which provide crucial inputs to deepen our understanding of Titan’s stratospheric chemistry.

Author(s): Delphine Nna-Mvondo1, Carrie Anderson1, Robert E. Samuelson1
Institution(s): 1. NASA Goddard Space Flight Center

314 – Stellar Abundances in Dwarf Galaxies VI: Massive Satellites of the Milky Way

The Apache Point Observatory Galactic Evolution Experiment provides the opportunity of measuring elemental abundances for C, N, O, Na, Mg, Al, Si, P, K, Ca, V, Cr, Mn, Fe, Co, and Ni in vast numbers of stars. We analyze the chemical-abundance patterns of

Author(s): Carrie Anderson1, Robert E. Samuelson1
Institution(s): 1. NASA Goddard Space Flight Center
these elements for 158 red giant stars belonging to the Sagittarius dwarf galaxy (Sgr). This is the largest sample of Sgr stars with detailed chemical abundances, and it is the first time that C, N, P, K, V, Cr, Co, and Ni have been studied at high resolution in this galaxy. We find that the Sgr stars with [Fe/H] > -0.8 are deficient in all elemental abundance ratios (expressed as X/Fe) relative to the Milky Way, suggesting that the Sgr stars observed today were formed from gas that was less enriched by Type II SNe than stars formed in the Milky Way. By examining the relative deficiencies of the hydrostatic (O, Na, Mg, and Al) and explosive (Si, P, K, and Mn) elements, our analysis supports the argument that previous generations of Sgr stars were formed with a top-light initial mass function, one lacking the most massive stars that would normally pollute the interstellar medium with the hydrostatic elements. We use a simple chemical-evolution model, flexCE, to further support our claim and conclude that recent stellar generations of Fornax and the Large Magellanic Cloud could also have formed according to a top-light initial mass function. We then exploit the unique chemical abundance patterns of the Sgr core to trace stars belonging to the Sgr tidal streams elsewhere in the Milky Way.

Author(s): Sten Hasselquist1, Matthew D. Shetrone4, Verne V. Smith2, Jon A. Holtzman1, Andrew McWilliam3
Institution(s): 1. New Mexico State University, 2. NOAO, 3. The Carnegie Observatories, 4. University of Texas at Austin, McDonald Observatory
Contributing team(s): The APOGEE Team

314.02 – Recreating the chemical evolution of the Sagittarius dwarf spheroidal from its tidal debris

We present a detailed chemical analysis of the Sagittarius (Sgr) tidal stream based on high-resolution Gemini+GRACES spectra of 42 members of the highest surface brightness portions of both the trailing and leading arms of the Sgr stream. We select Sgr tidal stream candidates using a 2MASS+WISE color-color selection, combined with LAMOST radial velocities, allowing us to efficiently select Sgr stream members with little contamination from field stars. Sgr is a recently infalling, currently disrupting dwarf spheroidal galaxy, with roughly 70% of the luminosity of the Sgr system residing in the tidal streams. With this study, we provide a link between the (known) chemical properties in the intact Sgr core and the significant portion of the Sgr system's luminosity that is estimated to currently reside in the streams. In this talk, we focus on abundances of alpha-elements, but we will also analyze neutron-capture (both r- and s-process) and iron-peak species. We compare our chemical abundances to the few existing measurements in the stream as well as the numerous results in the Sgr core.

Author(s): Jeffrey L. Carlin2, Allyson Sheffield1, Katia M. L. Cunha4, Verne V. Smith3
Institution(s): 1. LaGuardia Community College, City University of New York, 2. LSST, 3. NOAO, 4. Steward Observatory/Univ. of Arizona

314.03 – The Most Metal-poor Stars in the Large Magellanic Cloud

The chemical abundances of the most metal-poor stars in a galaxy can be used to investigate the earliest stages of its formation and chemical evolution. Differences between the abundances of the most metal-poor stars in the Milky Way and in its satellite dwarf galaxies have been noted and provide the strongest available constraints on the earliest stages of general galactic chemical evolution models. However, the masses of the Milky Way and its satellite dwarf galaxies differ by four orders of magnitude, leaving a gap in our knowledge of the early chemical evolution of intermediate mass galaxies like the Magellanic Clouds. To close that gap, we have initiated a survey of the metal-poor stellar populations of the Magellanic Clouds using the mid-infrared metal-poor star selection of Schlaufman & Casey (2014). We have discovered the three most metal-poor giant stars known in the Large Magellanic Cloud (LMC) and reobserved the previous record holder. The stars have metallicities in the range -2.70 < [Fe/H] < -2.00 and show r-process enhancement: one has [Eu II/Fe] = +1.65 and two others have [Eu II/Fe] = +0.65. The probability that four randomly selected very metal-poor stars in the halo of the Milky Way are as r-process enhanced is 0.0002. For that reason, the early chemical enrichment of the heaviest elements in the LMC and Milky Way were qualitatively different. It is also suggestive of a possible chemical link between the LMC and the ultra-faint dwarf galaxies nearby with evidence of r-process enhancement (e.g., Reticulum II and Tucana III). Like Reticulum II, the most metal-poor star in our LMC sample is the only one not enhanced in r-process elements.

Author(s): Kevin C Schlaufman1
Institution(s): 1. Johns Hopkins University

315 – Stellar Topics II

315.01 – Structure in the Disk of epsilon Aurigae – Analysis of ARCES and TripleSpec data from the 2010 eclipse

Worldwide interest in the recent eclipse of epsilon Aurigae resulted in the generation of several extensive data sets, including high resolution spectroscopic monitoring. This lead to the discovery, among other things, of the existence of a mass transfer stream, seen notably during third contact. We explored spectroscopic facets of the mass transfer stream during third contact, using high resolution spectra obtained with the ARCES and TripleSpec instruments at Apache Point Observatory. One hundred and sixteen epochs of data were obtained between 2009 and 2012, and equivalent widths and line velocities measured for high versus low eccentricity accretion disk lines. These datasets also enable greater detail to be measured of the mid-eclipse enhancement of the He I 10830A line, and the discovery of the P Cygni shape of the Pa-beta line at third contact. We found evidence of higher speed material, associated with the mass transfer stream, persisting between third and fourth eclipse contacts. We visualized the disk and stream interaction using SHAPE software, and used CLOUDY software to estimate that the source of the enhanced He I 10830A absorption arises from a region with log nH = 11 cm^-3 and temperature of 20,000 K, consistent with a mid-B type central star. We thank the following for their contributions to this paper: William Ketzeback, John Barentine, Jeffrey Coughlin, Robin Leadbeater, Gabrelle Saurage, and others. This paper has been submitted to Monthly Notices.

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Institution(s): 1. University of Denver
Contributing team(s): The ARCES Team: W.Ketzeback (ApachePointObservatory - APO), J.Barentine (DarkSkyAssociation), A.Bradley (APO), J.Coughlin (SETI Institute), J.Dembicky (APO), S.Hawley (Washington), J.Huehnerhoff (Washington), R.Leadbeater (ThreeHillsObservatory), R.McMillan (APO), G.Saurage (SOFIA), S.Schmidt (OhioState), N.Ule (NewMexicoState), G.Wallerstein (Washington), and D.York (Chicago)

315.02 – MESA models for the evolutionary status of the epsilon Aurigae disk-eclipsed binary system

The brightest member of the class of disk-eclipsed binary stars is the Algol-like long-period binary, epsilon Aurigae (HD 31964, F0Iap + disk, http://adsabs.harvard.edu/abs/2016SPIE.9907E..17S ). Using MESA (Modules for Experiments in Stellar Astrophysics, version 9575), we have made an evaluation of its evolutionary state. We sought to satisfy several observational constraints, including: (1) requiring evolutionary tracks to pass close to the current temperature and luminosity of the primary star; (2) obtaining a period near the observed value of 27.1 years; (3) matching a mass function of 3.0; (4) concurrent Roche lobe overflow and mass
transfer; (g) an isotopic ratio $^{12}$C / $^{13}$C = 5 and, (6) matching the interferometrically determined angular diameter. A MESA model starting with binary masses of $9.85 + 4.5$ solar masses, with a 100 day initial period, produces a $1.2 + 10.6$ solar masses result having a 5.47 day period, plus a single digit $^{12}$C / $^{13}$C ratio. These values were reached near an age of 20 Myr, when the donor star comes close to the observed luminosity and temperature for epsilon Aurigae A, as a post-RGB/pre-AGB star.

Contemporaneously, the accretor then appears as an upper main sequence, early B-type star. This benchmark model can provide a basis for further exploration of this interacting binary, and other long period binary stars. This report has been submitted to MNRAS, along with parallel investigations of mass transfer stream and disk sub-structure. The authors are grateful to the estate of William Herschel Womble for the support of astronomy at the University of Denver.

**Author(s):** Robert E. Stencel1, Justus Gibson1
**Institution(s):** 1. Univ. of Denver

### 315.03 – Astronomy in Denver: Spectropolarimetric Observations of 5 Wolf-Rayet Binary Stars with SALT/RSS

Mass loss from massive stars is an important yet poorly understood factor in shaping their evolution. Wolf-Rayet (WR) stars are of particular interest due to their stellar winds, which create large regions of circumstellar material (CSM). They are also supernova and possible gamma-ray burst (GRB) progenitors. Like other massive stars, WR stars often occur in binaries, where interaction can affect their mass loss rates and provide the rapid rotation thought to be required for GRB production. The diagnostic tool of spectropolarimetry, along with the potentially eclipsing nature of a binary system, helps us to better characterize the CSM created by the stars’ colliding winds. Thus, we can determine mass loss rates and infer rapid rotation. We present spectropolarimetric results for five WR+O eclipsing binary systems, obtained with the Robert Stobie Spectrograph at the South African Large Telescope, between April 2017 and April 2018. The data allow us to map both continuum and emission line polarization variations with phase, which constrains where different CSM components scatter light in the systems. We discuss our initial findings and interpretations of the polarimetric variability in each binary system, and compare the systems.

**Author(s):** Andrew Fullard2, Zyed Ansary2, Daniel Azancot Luchtan2, Hunter Gallegos2, Martin Luepker2, Jennifer L. Hoffman2, Kenneth H. Nordieck3
**Institution(s):** 1. Univ. of Wisconsin, 2. University of Denver

### 315.04 – Using White Dwarf Companions to Constrain Mass Transfer Physics

Complete membership studies of old open clusters reveal that 25% of the evolved stars follow pathways in stellar evolution that are impacted by binary evolution. Recent studies show that the majority of blue straggler stars, traditionally defined to be stars brighter and bluer than the corresponding main sequence turnoff, are formed through mass transfer from a giant star onto a main sequence companion, resulting in a white dwarf in a binary system with a blue straggler. We will present constraints on the histories and mass transfer efficiencies for two blue straggler-white dwarf binaries in open cluster NGC 188. The constraints are a result of measuring white dwarf cooling temperatures and surface gravities with HST COS far-ultraviolet spectroscopy. This information sets both the timeline for mass transfer and the stellar masses in the pre-mass transfer binary, allowing us to constrain aspects of the mass transfer physics. One system is formed through Case C mass transfer, leaving a CO-core white dwarf, and provides an interesting test case for mass transfer from an asymptotic giant branch star in an eccentric system. The other system formed through Case B mass transfer, leaving a He-core white dwarf, and challenges our current understanding of the expected regimes for stable mass transfer from red giant branch stars.

**Author(s):** Natalie M. Gosnell2, Emily Leiner6, Aaron M. Geller4, Christian Knigge5, Robert D. Mathieu6, Alison Sills3, Nathan Leigh1

### 315.05 – Flare Frequency Distribution at Low Energies in GALEX UV

The gPhoton toolkit and database of GALEX photon events permits measurement of flares with energies as small as $\sim 10^4$ ergs in the two GALEX UV bandpasses. Following a previously reported search for flaring on several thousand M dwarfs observed by GALEX, we present initial results on the flare frequency as a function of energy and stellar type at energies $\sim 10^4$ ergs.

**Author(s):** Chase Million3, Scott W. Fleming4, Rachel A. Osten4, Clara Brasseur4, Luciana Bianchi2, Bernie Shiao4, R. O. Parke Loyd4, Evgenya L Shkolnik1

### 315.06 – The Transiting Dust of Boyajian's Star

From May to October of 2017, Boyajian's Star displayed four days-long dips in observed flux, which are referred to as “Elsie,” “Celeste,” “Skara Brae,” and “Angkor” (Boyajian et al. 2018). This Elsie family dip event was monitored with the Las Cumbres Observatory in three bands, B, r’, and i’. Looking at each dip individually, we analyze the multi-band photometry for wavelength dependency in dip depth to constrain properties of the transiting material. We find that all of the dips show non-grey extinction and are consistent with optically thin dust. Interpreting the dips as transiting dust clouds, we constrain the properties of the dust grains and find that the average grain radius is $<1$ micron, assuming silicate composition. This wavelength dependency and grain size is inconsistent with observed properties of the long-term “secular” dimming (Meng et al. 2017), suggesting that the dust causing the dips is from a separate population.

**Author(s):** Eva Bodman1, Tyler G Ellis2, Tabetha S. Boyajian2, Jason Wright3
**Institution(s):** 1. Arizona State University, 2. Louisiana State University, 3. Pennsylvania State University

### 316 – Plenary Talk: Status of the Daniel K. Inouye Solar Telescope: Unraveling the Mysteries the Sun, Thomas Rimmele (NSO)

**316.01 – Status of the Daniel K. Inouye Solar Telescope: unravelling the mysteries the Sun.**

The 4m Daniel K. Inouye Solar Telescope (DKIST) currently under construction on Haleakala, Maui will be the world’s largest solar telescope. Designed to meet the needs of critical high resolution and high sensitivity spectral and polarimetric observations of the sun, this facility will perform key observations of our nearest star that matters most to humankind. DKIST’s superb resolution and sensitivity will enable astronomers to address many of the fundamental problems in solar and stellar astrophysics, including the origin of stellar magnetism, the mechanisms of coronal heating and drivers of the solar wind, flares, coronal mass ejections and variability in solar and stellar output. DKIST will also address basic research aspects of Space
Weather and help improve predictive capabilities. In combination with synoptic observations and theoretical modeling DKIST will unravel the many remaining mysteries of the Sun. The construction of DKIST is progressing on schedule with 80% of the facility complete. Operations are scheduled to begin early 2020. DKIST will replace the NSO facilities on Kitt Peak and Sac Peak with a national facility with worldwide unique capabilities. The design allows DKIST to operate as a coronagraph. Taking advantage of its large aperture and infrared polarimeters DKIST will be capable to routinely measure the currently illusive coronal magnetic fields. The state-of-the-art adaptive optics system provides diffraction limited imaging and the ability to resolve features approximately 20 km on the Sun. Achieving this resolution is critical for the ability to observe magnetic structures at their intrinsic, fundamental scales. Five instruments will be available at the start of operations, four of which will provide highly sensitive measurements of solar magnetic fields throughout the solar atmosphere -- from the photosphere to the corona. The data from these instruments will be distributed to the world wide community via the NSO/DKIST data center located in Boulder. We present examples of science objectives and provide an overview of the facility and project status, including the ongoing efforts of the community to develop the critical science plan for the first 2-3 years of operations.


Contributing team(s): DKIST Team

317 – Stellar Topics Poster Session

317.01 – Short duration flares in GALEX data
Flares on cool stars indicate short time-scale magnetic reconnection processes that provide temporary increases in the stellar radiative output. While recent work has focused on long-duration flares from solar-like stars and those of lower mass, the existence of short-duration flares in the ultraviolet has not been systematically probed before. We will present an interesting population of short duration flares we discovered in a sample of ~37,000 light curves observed from 2009-2012 by the GALEX and Kepler missions. These flares range in duration from under a minute to a few minutes and are almost entirely distinct from a previous flare survey of Kepler data. We were able to detect this unique population of flares because the time resolution of the GALEX data allowed us to construct light curves with a 10 second cadence and thus detect shorter duration flares than could be detected within Kepler data. We applied algorithmic flare detection to a sample of ~37,000 stars, and identified a final count of 2,065 flares on 1,121 stars. We discuss the implication of these events for the flare frequency distributions of solar-like stars.

Author(s): Clara Brasseur1, Rachel A. Osten1
Institution(s): 1. Space Telescope Science Institute

317.02 – A Phenomenological Two-Ribbon Model for Spatially Unresolved Observations of Stellar Flares
Solar flares and flares that occur in much more magnetically active stars share some striking properties, such as the observed Neupert effect. However, stellar flares with the most impressive multi-wavelength data sets are typically much more energetic than solar flares, thus making robust connections difficult to establish. Whereas solar data have the advantage of high spatial resolution providing critical information about the development of flare ribbons, the major advantage of stellar flare data is the readily available broad-wavelength coverage of the white-light radiation and the Balmer jump spectral region. Due to the lack of direct spatial resolution for stellar flares and rarely coverage of the Balmer jump region for solar flares, it is not clear how to make a direct comparison. I will present a new method for modeling stellar flares based on high spatial resolution information of solar flare two-ribbon development for comparisons of the physics of their observed phenomena, such as the red-wing asymmetries in chromospheric lines and the white-light continuum radiation. The new modeling method combines aspects of “multi-thread” modeling and 1D radiative-hydrodynamic modeling. Our algorithm is important for interpreting the impulsive phase of superflares in young G dwarfs in Kepler and understanding how hour-long decay timescales are attained in the gradual phase of some very energetic stellar flares.

Author(s): Adam Kowalski1
Institution(s): 1. University of Colorado Boulder

317.03 – Computing Models of M-type Host Stars and their Panchromatic Spectral Output
We have begun a program of computing state-of-the-art model atmospheres from the photospheres to the coronae of M stars that are the host stars of known exoplanets. For each model we are computing the emergent radiation at all wavelengths that are critical for assessing photochemistry and mass-loss from exoplanet atmospheres. In particular, we are computing the stellar extreme ultraviolet radiation that drives hydrodynamic mass loss from exoplanet atmospheres and is essential for determining whether an exoplanet is habitable. The model atmospheres are computed with the SSRPM radiative transfer/statistical equilibrium code developed by Dr. Juan Fontenla. The code solves for the non-LTE statistical equilibrium populations of 18,538 levels of 52 atomic and ion species and computes the radiation from all species (435,986 spectral lines) and about 20,000,000 spectral lines of 20 diatomic species.

The first model computed in this program was for the modestly active M1.5 V star GJ 832 by Fontenla et al. (ApJ 830, 152 (2016)). We will report on a preliminary model for the more active M5 V star GJ 876 and compare this model and its emergent spectrum with GJ 832. In the future, we will compute and intercompare semi-empirical models and spectra for all of the stars observed with the HST MUSCLES Treasury Survey, the Mega-MUSCLES Treasury Survey, and additional stars including Proxima Cen and Trappist-1.

This multiyear theory program is supported by a grant from the Space Telescope Science Institute.

Author(s): Jeffrey Linsky1, Dennis Tilipman1, Kevin France1
Institution(s): 1. Univ. of Colorado

317.04 – The Abundances of the Fe Group Elements in AV 304, an Abundance Standard in the Small Magellanic Cloud
AV 304 is a B0.5 IV field star in the Small Magellanic Cloud with ultra-sharp spectral lines that has emerged as an abundance standard. We have combined recent spectrophotometric observations from the Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope with archival data from the Far Ultraviolet Spectroscopic Explorer (FUSE) and ESO’s VLT/UVES to determine the abundances of the Fe group elements (Ti, V, Cr, Mn, Fe, Co, & Ni). The analysis was carried through using the Hubeny/Lanz NLTE programs TLUSTY/SYNSPEC. The COS observations were secured with the G130M, G160M, G185M, and G225M gratings. Combined with the FUSE data, we have
achieved spectral coverage in the UV from 950 to 2400 Å. Measurable lines from the Fe group, except for a very few multiplets of Fe II, III are not observed in optical spectra. The following stellar parameters were found: Teff = 27500±500 K, log g = 3.7±0.1 cm/s^2, Vturb= 1±1 km/s, and v sin i = 8 ±2 km/s. The Fe abundance appears to be only slightly lower than the mean depletion in the SMC, but the other Fe group elements are underabundant by 0.3 dex or more. This study confirmed the low abundance of nitrogen (-1.25 dex relative to the solar value) that was reported by Peters & Adelman (ASP Conf. Series, 348, p. 136, 2006). Whereas the light elements are delivered to the ISM by core-collapse supernovae (CCSNe), the Fe group elements are believed to come mostly from low/intermediate mass binaries containing white dwarfs that undergo SNe IIa explosions. A single SNe IIa can deliver 0.5 solar masses of pure Fe (and maybe Mn) to the ISM compared with about 0.07 solar masses from a CCSNe. It appears that there is very little processed material from its interior in the atmosphere of AV 304 and that the star did not form from an interstellar cloud that was enriched by material from earlier supernova activity. Support from STScI grants HST-GO-14081.002 and HST-GO-13346.022, and USC's Women in Science and Engineering (WiSE) program is greatly appreciated.


317.06 – A Study of Inner Disk Gas around Young Stars in the Lupus Complex

We present a study of molecular hydrogen at the surfaces of the disks around five young stars in the Lupus complex: RY Lupi, RU Lupi, MY Lupi, Sz 68, and TYC 7851. Each system was observed with the Cosmic Origins Spectrograph (COS) onboard the Hubble Space Telescope (HST), and we detect a population of fluorescent H2 in all five sources. The temperatures required for Lyα fluorescence to proceed (T ~ 1500-2500 K) place the gas within ~15 AU of the central stars. We have used these features to extract the radial distribution of H2 in the inner disk, where planet formation may already be taking place. The objects presented here have very different outer disk morphologies, as seen by ALMA via 890 micron dust continuum emission, ranging from full disks with no signs of cavities to systems with large regions that are clearly depleted (e.g. TYC 7851, with a cavity extending to 75 and 60 AU in dust and gas, respectively). Our results are interpreted in conjunction with sub-mm data from the five systems in an effort to piece together a more complete picture of the overall disk structure. We have previously applied this multi-wavelength approach to T Tau, including 4.7 micron IR-CO emission in our analysis. These IR-CO and UV-H2 observations were combined with 10 micron silicate emission, the 890 micron dust continuum, and 1.3 mm CO observations from the literature to infer a gapped structure in the inner disk. This single system has served as a testing ground for the larger Lupus complex sample, which we compare here to examine any trends between the outer disk morphology and inner disk gas distributions.

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Institution(s): 1. California Institute of Technology, 2. University of Colorado Boulder

317.07 – Classification of Hot Stars by Disk Variability using Ha Line Emission Characteristics

The variability associated with circumstellar disks around hot and massive stars has been observed on time scales ranging from less than a day to decades. Variations detected in line emission from circumstellar disks on long time scales are typically attributed to disk-growth and disk-loss events. However, in order to fully describe and model such phenomena, adequate spectroscopic observations over long time scales are needed. In this project, we conduct a comprehensive study that is based on spectra recorded over a 14-year period (2005 to 2018) of roughly 100 B-type stars. Using results from a representative sample of over 20 targets, we illustrate how the Hα emission line, one of the most prominent emission features from circumstellar disks, can be used to monitor the variability associated with these systems. Using high-resolution spectra, we utilize line emission characteristics such as equivalent width, peak strength(s), and line-width to setup a classification scheme that describes different types of variabilities. This in turn can be used to divide the systems in disk-growth, disk-loss, variable and stable categories. With additional numerical disk modeling, the recorded variations based on emission line characteristics can also be used to describe changes in disk temperature and density structure. The aim is to develop a tool to help further our understanding of the processes behind the production and eventual dissipation of the circumstellar disks found in hot stars. This work has been supported by NSF grant AST-1614983.

Author(s): Christian Hoyt Hannah1, W. Glennon Fagan1, Christopher Tycner1

Institution(s): 1. Central Michigan University

317.08 – Creating Compositionally-Driven Debris Disk Dust Models

Debris disks play a key role in exoplanet research; planetary formation and composition can be inferred from the nature of the circumstellar disk. In order to characterize the properties of the circumstellar disk dust, we create models of debris disks in order to find the composition. We apply Mie theory to calculate the dust absorption and emission within debris disks. We have data on nine targets from Spitzer and Hubble Space Telescope. The Spitzer data includes mid-IR spectroscopy and photometry. We have spatially-resolved optical and near-IR images of the disks from HST. Our goal is to compare this data to the model. By using a model that fits for photometric and mid-IR data simultaneously, we gain a deeper understanding of the structure and composition of the debris disk systems.

Author(s): Mara Zimmerman3, Hannah Jang-Condell3, Glenn Schneider2, Christine Chen1, Chris Stark1


317.09 – Modeling Protopstar Envelopes and Disks Seen With ALMA: A Focus on L1527 Kinematics

ALMA probes continuum and spectral line emission from protostars that comes from both the envelope and circumstellar disk. The dust and gas emit on a variety of spatial scales, ranging from sub-arcseconds for disks to roughly 10 arcseconds for envelopes for nearby protostars. We present models of what ALMA should detect that incorporate a self-consistent collapse solution, radiative transfer, and realistic dust properties. Molecular abundances are also calculated; we present results for CO and isotopologues for the Class 0 source L1527. Results for the outer disk show that there can be significant differences from standard assumptions due to the effect of CO freeze out and non-Keplerian dynamics.

Author(s): Susan Terebey1, Lizxandra Flores Rivera1, Karen Willacy2

Institution(s): 1. Cal. State Univ. at Los Angeles, 2. Jet Propulsion Laboratory/California Institute of Technology

317.10 – First Precision Photometric Observations and Analyses of The Totally Eclipsing, Solar Type Binary, V573 Pegasi

CCD, VRI light curves of V573 Peg were taken in 26,27 September and 2, 4 and 6 October, 2017 at the Dark Sky Observatory in North Carolina with the 0.81-m reflector of Appalachian State University by D. Caton. V573 Peg was discovered by the SAVS survey which classified it as a V = 0.51 amplitude, EW variable. They included a rough spectrum identifying the binary was about a type G, although the period would indicate it is an F-type contact binary. Five times of minimum light were calculated, two
primary eclipses and three secondary, from our present observations:

\[ \text{HJD I} = 2458023.6420 \pm 0.0012, \quad 2458028.6522 \pm 0.0021, \]
\[ \text{HJD II} = 2458022.5991 \pm 0.0011, \quad 2458023.8510 \pm 0.0010 \quad \text{and} \]
\[ 2458028.8608 \pm 0.0005, \]

The following linear and quadratic ephemerides were determined from all available times of minimum light.

\[ \text{JD Hel Min I} = 2456876.49437 \pm 0.00078d + 0.41745021 \pm 0. \]
\[ \times E, \quad +0. \]

\[ \text{JD Hel Min I} = 2456876.49580 \pm 0.00023d + 0. \]
\[ 417448601 \pm 0.00000083 \times E - \]
\[ 0.000000000274 \times E \pm 0.000000000012 \times E^2 \]

A 14-year period study (24 times of minimum light) revealed that the orbital period decreasing with a high level of confidence, possibly due to magnetic braking. The mass ratio is found to be somewhat extreme, \( M_2/M_1 = 0.2692 \pm 0.0006 \).

Its Roche Lobe fill-out is 25%. The solution had no need of spots. The temperature difference of the components is almost \( 130 \) K, with the hotter as the hotter star, so it is a W-type W UMa Binary. The inclination is \( 80.4 \pm 0.1 \) degrees. The secondary eclipse shows a time of constant light with an eclipse duration of 24 minutes. More details of our results will be given at the meeting.

**Author(s):** Ronald G. Samec3, Daniel B. Caton1, Danny R Faulkner2

**Institution(s):** 1. Appalachian State University, 2. Johnson Observatory, 3. Pisgah Astronomical Research Institute

**Contributing team(s):** Ronald G Samec

### 317.11 – Period Study and Analyses of 2017 Observations of the Totally Eclipsing, Solar Type Binary, MT Camelopardalis

We report here on a period study and the analysis of BVRc-Lc light curves (taken in 2017) of MT Cam (GSC03737-01085), which is a solar type (T ~ 5500K) eclipsing binary. D. Caton observed MT Cam on 05, 14, 15, 16, and 17, December 2017 with the 0.81-m reflector at Dark Sky Observatory. Six times of minimum light were calculated from four primary eclipses and two secondary eclipses:

\[ \text{HJD I} = 24 \text{58092.4937} \pm 0.0002, \quad 24 \text{58102.7460} \pm 0.0021, \]
\[ 24 \text{58104.5769} \pm 0.0002, \quad 24 \text{58104.9434} \pm 0.0029 \]

\[ \text{HJD II} = 24 \text{58103.6610} \pm 0.0001, \quad 24 \text{58104.7607} \pm 0.0020, \]

Six times of minimum light were also calculated from data taken by Terrell, Gross, and Cooney, in their 2016 and 2004 observations (reported in IBVS #6166; TGC, hereafter). In addition, six more times of minimum light were taken from the literature. From all 18 times of minimum light, we determined the following light elements:

\[ \text{JD Hel Min I} = 24 \text{58102.7460(4)} + 0.36613937(5) \times E \]

We found the orbital period was constant over the 14 years spanning all observations. We note that TGC found a slightly increasing period. However, our results were obtained from a period study rather than comparison of observations from only two epochs by the Wilson-Devinney (W-D) Program. A BVRc-Lc Johnson-Cousins filtered simultaneous W-D Program solution gives a mass ratio (0.3385±0.0014) very nearly the same as TGC’s (0.347±0.005), and a component temperature difference of only \( -40 \) K. As with TGC, no spot was needed in the modeling. Our modeling (beginning with Binary Maker 3.0 fits) was done without prior knowledge of TGC’s. This shows the agreement achieved when independent analyses are done with the W-D code. The present observations were taken 1.8 years later than the last curves by TGC, so some variation is expected.

The Roche Lobe fill-out of the binary is \( \sim 13\% \) and the inclination is \( \sim 83.5 \) degrees. The system is a shallow contact W-type W UMa Binary, albeit, the amplitudes of the primary and secondary eclipse are very nearly identical. An eclipse duration of \( \sim 21 \) minutes was determined for the secondary eclipse and the light curve solution. Additional and more detailed information is given in the poster paper.

**Author(s):** Daniel R Faulkner2, Ronald G. Samec3, Daniel B. Caton1

**Institution(s):** 1. Appalachian State University, 2. Johnson Observatory, 3. Pisgah Astronomical Research Institute

### 317.12 – Stability of Stellar Periods in the Hyades and Taurus

K2 has opened to us the study of high-precision light curves from which we can derive stellar rotation periods. We have presented period distribution studies for the Pleiades, Praesepe, Upper Sco and Rho Oph. But, how stable are the periods we are deriving from them? Early ground-based work in Orion (Rebull 2001) suggested that, for the youngest stars, about half the stars had sufficiently different spot distributions in two consecutive years such that periods could not be recovered in the second year. However, now that we have K2, precision and diurnal windowing functions are no longer really much of a concern. For a handful of stars in Hyades and Taurus, the K2 spacecraft monitored them for two non-consecutive 70d windows (campaigns 4, 2015 Feb and 13, 2017 Mar). In this poster, we examine whether or not the light curves are similar in the two epochs, and how accurately the same period can be recovered.

**Author(s):** Luisa M. Rebull1, John R. Stauffer1

**Institution(s):** 1. Caltech

**Contributing team(s):** K2 Clusters Team

### 317.13 – Mapping photometric metallicities in the Galactic halo using broadband photometry

An important objective of modern Astrophysics is to trace the history of galaxies and the dynamics of their formations. The outer regions of the Milky Way, including the Galactic halo, could potentially elucidate the evolutionary history of our galaxy. In this study, we make use of extensive DD050 polarization combined with SDSS broadband photometry to select giant stars reaching to 90 kpc. Photometric metallicities, calibrated by overlapping spectroscopic data (SDSS, APOGEE and LAMOST), and distances are calculated for all giant stars. Using these metallicities and distances, we construct metallicity distribution functions (MDFs) from these stars. We study the MDFs for information pertaining to the accretion history of the Milky Way.

**Author(s):** Samuel David Henbestreit4, David L. Nidever5, Jeffrey A. Munn2, Steven R. Majewski3

**Institution(s):** 1. Montana State University, 2. U.S. Naval Observatory, 3. University of Virginia

### 317.14 – Chandra X-ray Time-Domain Study of Alpha Centauri AB, Procyon, and their Environ

For more than a decade, Chandra X-ray Observatory has been monitoring the central AB binary (G2V+K1V) of the α Centauri triple system with semi-annual pointings, using the High-Resolution Camera. This study has been extended in recent years to the mid-F subgiant, Procyon. The main objective is to follow the coronal (T ~1MK) activity variations of the three stars, analogous to the Sun’s 11-year sunspot cycle. Tentative periods of 20 yr and 8yr have been deduced for α Cent A and B, respectively; but so far Procyon has shown only a slow, very modest decline in count rate, which could well reflect a slight instrumental degradation rather than intrinsic behavior. The negligible high-energy variability of Procyon sits in stark contrast to the dramatic factor of several to ten changes in the X-ray luminosities of α Cent AB and the Sun over their respective cycles. Further, although sunlike α Cent A has been observed by successive generations of X-ray observatories for nearly four decades, albeit sporadically, there are key gaps in the coverage that affect the determination of the cycle period. In fact, the most recent pointings suggest a downturn in A's count rate that might be signaling a shorter, more solar-like cycle following a delayed minimum in the 2005-2010 time frame (perhaps an exaggerated version of the extended solar minimum between recent Cycles 23 and 24).
Beyond the coronal cycles of the three stars, the sequence of periodic X-ray images represents a unique time-domain history concerning steady as well as variable sources in the two 30′ x 30′ fields. The most conspicuous of the variable objects -- in the α Cen field -- will be described here.

Author(s): Thomas R. Ayres
Institution(s): 1. University of Colorado

317.15 – Optical and X-ray studies of Compact X-ray Binaries in NGC 5904
Due to their high stellar densities, globular cluster systems trigger various dynamical interactions, such as the formation of compact X-ray binaries. Stellar collisional frequencies have been correlated to the number of X-ray sources detected in various clusters and we hope to measure this correlation for NGC 5904. Optical fluxes of sources from archival HST images of NGC 5904 have been measured using a DOLPHOT PSF photometry in the UV, optical and near-infrared. We developed a data analysis pipeline to process the fluxes of tens of thousands of objects using awk, python and DOLPHOT. We plot color magnitude diagrams in different photometric bands in order to identify outliers that could be X-ray binaries, since they do not evolve the same way as singular stars. Aligning previously measured astrometric data for X-ray sources in NGC 5904 from Chandra with archival astrometric data from HST will filter out the outlier objects that are not X-ray producing, and provide a sample of compact binary systems that are responsible for X-ray emission in NGC 5904. Furthermore, previously measured X-ray fluxes of NGC 5904 from Chandra have also been used to measure the X-ray to optical upstream of the primary reconfinement shock. The light curves so produced are similar to those of blazars, although turbulence on sub-grid scales is likely to be important for the variability on the shortest timescales.

Author(s): Andrew Neugarten1, Tatsuya Akiba1, Vayujeet Gokhale1
Institution(s): 1. Truman State University

318 – AGN, QAOs and Blazars Poster Session

318.01 – Three-dimensional relativistic jet simulations and the morphological classification of radio-loud AGN
We have computed a suite of simulations of propagating three-dimensional relativistic jets, involving substantial ranges of initial jet Lorentz factors and ratios of jet density to external medium density. These allow us to categorize the respective AGN into Fanaroff-Riley class I (jet dominated) and FR class II (lobe-dominated) based upon the stability and morphology of the simulations. We used the Athena code to produce a substantial collection of large 3D variations of jets, many of which propagate stably and quickly for over 100 jet radii, but others of which eventually go unstable and fill up slower advancing lobes. Most of these simulations have jet-to-ambient medium densities between 0.005 and 0.5 and velocities between 0.90c and 0.995c. Comparing the times when some jets go unstable to these initial parameters allow us to find a threshold where radio-loud AGNs transition from class I to class II. With these high resolution fully 3D relativistic simulations we can represent the jets more accurately and thus improve upon and refine earlier results that were based on 2D simulations.

Author(s): Terance Schuh1, Yutong Li1, Geena Elghossain1, Paul J. Wiita1
Institution(s): 1. The College of New Jersey

318.02 – Radio-loud AGN Variability from Propagating Relativistic Jets
The great majority of variable emission in radio-loud AGNs is understood to arise from the relativistic flows of plasma along two oppositely directed jets. We study this process using the Athena hydrodynamics code to simulate propagating three-dimensional relativistic jets for a wide range of input jet velocities and jet-to-ambient matter density ratios. We then focus on those simulations that remain essentially stable for extended distances (60-120 times the jet radius). Adopting results for the densities, pressures and velocities from these propagating simulations we estimate emissivities from each cell. The observed emissivity from each cell is strongly dependent upon its variable Doppler boosting factor, which depends upon the changing bulk velocities in those zones with respect to our viewing angle to the jet. We then sum the approximations to the fluxes from a large number of zones and identify the types of compact X-ray binaries responsible for the X-ray emissions in NGC 5904. We gratefully acknowledge the support from the Illinois Space Grant Consortium.

Author(s): Vanshree Bhalotia1, Bernhard Beck-Winchatz1
Institution(s): 1. DePaul

317.16 – Photometric Analysis of Eclipsing Binary Az Vir
We present photometric analysis of the eclipsing binary star system Az Vir. Standard BVR filter data were obtained using the 17-inch PlaneWave Instruments CDK telescope at the Truman State University Observatory in Kirksville, Mo and the 31-inch NURO telescope at the Lowell Observatory complex in Flagstaff, AZ. We apply an eight-term truncated Fourier fit to the light curves generated from these data to confirm the classification of Az Vir as a W Ursae Majoris-type eclipsing variable, using criteria specified by Rucinski (1997). We also calculate the values for the O’Connell Effect Ratio (OER) and the Light Curve Asymmetry (LCA) to quantify the asymmetry in the BVR light curves. In addition, we use data provided by the SuperWASP mission to perform long term O-C (observed minus calculated) analysis on the system to determine if and how its period is changing.

Author(s): Andrew Neugarten1, Tatsuya Akiba1, Vayujeet Gokhale1
Institution(s): 1. Truman State University

318.03 – Studying AGN Activation in Galaxy Mergers
Simulations predict that galaxy mergers drive central gas inflows that result in a peak AGN fraction when the two galaxy bulges reach separations near 1 kpc. Moreover, observations have shown that the AGN fraction increases as the separation between two merging galaxies decreases from 100 kpc to 10 kpc; however, the trend has not yet been measured in the pivotal sub 10 kpc regime, where activity may drastically increase as the simulations suggest. We present a uniform sample of dual and offset AGN, which features AGN parameters (e.g., redshift, angular separation) and normalized cosmology-dependent parameters (e.g., physical separation, bolometric luminosity), using multi-wavelength observations (IR to X-ray) in this critical sub 10 kpc range. In addition, using galaxy merger simulations with GADGET-3, a smoothed particle hydrodynamics N-body code, we report how much time galaxy pairs spend at different separations during a merger. Using these results, we will discuss how galaxy bulge separation correlates to increases in the AGN fraction over varying timescales, and where AGN are primarily fueled during mergers with galaxy bulge separations < 10 kpc.

Author(s): James Negus1, Laura Blecha2
Institution(s): 1. The University of Colorado Boulder, 2. University of Florida

318.04 – The Circumnuclear Molecular Gas in Seyfert 1 versus Seyfert 2 Galaxies
The distribution and kinematics of the circumnuclear molecular gas in local Seyfert galaxies is investigated as part of the Keck OSIRIS Nearby AGN (KONA) survey. The two-dimensional distribution and kinematics of the molecular hydrogen, traced by 1-0 S(1) H2 2.12 micron emission, is probed down to scales of 5-30 parsecs in 20 type 1 and 20 type 2 Seyferts. Verifying previous
studies with smaller samples, these Seyferts show evidence of a circumnuclear disk of molecular gas that is both geometrically and optically thick. A comparison of the molecular hydrogen characteristics in type 1 and type 2 Seyferts indicates there is no significant difference in the flux distribution, the velocity dispersion, or the velocity/velocity dispersion ratio with the central 200 pc. We will also present upper limits on the central black hole mass based on the observed molecular gas kinematics.

Author(s): Kiana Kade
Institution(s): 1. University of Alaska Anchorage

318.05 – The KONA Survey: A Near-IR Perspective of the Circumnuclear Environment of local Seyfert Galaxies
With the Keck OSIRIS Nearby AGN, KONA, survey we simultaneously probe the stellar, molecular gas, and ionized gas kinematics within the central 400 pc of a sample of 40 local representative AGN. KONA's spatially resolved spectra enable an unprecedented study of the feeding and feedback processes in bona-fide AGN. We present a study the nuclear K-band properties of these local Seyferts, as well as the integrated molecular hydrogen and stellar distribution and kinematic at radii varying from 25 to 200 pc. We find that the luminosities of the unresolved Seyfert 1 sources at 2.1 microns are correlated with the hard X-ray luminosities over 3 orders of magnitude in both K-band and X-ray luminosities, implying that the majority of the emission is non-stellar. No correlation is found between the 2.1 microns luminosity and hard X-ray luminosity for the Seyfert 2 galaxies. The spatial extent and spectral slope of the Seyfert 2 galaxies indicates the presence of nuclear star formation and attenuating material (gas and dust), which is found to be compact in some galaxies and in others extended. A comparison of the circumnuclear stellar and molecular hydrogen properties (flux distribution, surface brightness, and velocity dispersion) in Seyfert 1 and 2 sources will also be presented.

Author(s): Erin K. S. Hicks, Francisco Mueller Sanchez, Matthew Arnold Malkan

318.06 – Distribution and Kinematics of Ionized Gas in the central 500pc of Seyfert Galaxies
We have characterized the spatial distribution and kinematics of the ionized hydrogen gas in a sample of 40 Seyfert galaxies as part of the KONA (Keck OSIRIS Nearby AGN) survey. An analysis of the narrow Brackett Gamma emission (2.16 microns) in the central 500 pc of these local AGN will be presented. Measurements include the azimuthal averages of the flux distribution, velocity dispersion, and emission line equivalent width. In addition, the excitation of the Brackett Gamma emission is considered using the ratio of its flux with that of molecular hydrogen (2.12 microns) as a diagnostic. A comparison of the circumnuclear narrow Brackett Gamma emission characteristics in the Seyfert type 1 and type 2 subsamples will also be presented.

Author(s): Ella Hyland, Erin K. S. Hicks, Kiana Kade
Institution(s): 1. University of Alaska Anchorage

318.07 – "Observing" the Circumnuclear Stars and Gas in Disk Galaxy Simulations
We present simulations based on theoretical models of common disk processes designed to represent potential inflow observed within the central 500 pc of local Seyfert galaxies. Mock observations of these n-body plus smoothed particle hydrodynamical simulations provide the conceptual framework in which to identify the driving inflow mechanism, for example nuclear bars, and to quantify to the inflow based on observable properties. From these mock observations the azimuthal average of the flux distribution, velocity dispersion, and velocity of both the stars and interstellar medium on scales of 50pc have been measured at a range of inclinations angles. A comparison of the simulated disk galaxies with these observed azimuthal averages in 40 Seyfert galaxies measured as part of the KONA (Keck OSIRIS Nearby AGN) survey will be presented.

Author(s): Angela Cook, Erin K. S. Hicks
Institution(s): 1. University of Alaska Anchorage

318.08 – Analysis of Microvariable Activity of BL Lacertae
BL Lac is a low-frequency peaked blazar (LBL) which emits synchrotron radiation at near-IR and optical wavelengths. Therefore optical observations are helpful in, among other things, studying the acceleration and cooling timescales of the electrons in the relativistic jets. We have made very high cadence observations of BL Lac over a number of nights with the Remote Observatory for Variable Object Research (ROVOR). Each night shows secular drift as well as a number of microvariable events lasting only a few minutes each. These data were then processed, compiled, and analyzed in order to examine the underlying mechanism that resulted in such activity. A geometric model is introduced that has worked well in the past on other similar sources. Our relativistic jet model consists of a slowly varying beamed source that already appears bright because it lies nearly to our line of sight. From this, individual relativistic components are ejected a few degrees relative to the aforementioned beaming angle. This is what we believe is responsible for the microvariability emission.

Author(s): Alberto C. Sadun, Masoud Asadi-Zeydabadi, J. Ward Moody
Institution(s): 1. Brigham Young University, 2. University of Colorado Denver

318.09 – GNIRS-DQS: A Gemini Near Infrared Spectrograph Distant Quasar Survey
We describe an ongoing three-year Gemini survey, launched in 2017, that will obtain near-infrared spectroscopy of 416 Sloan Digital Sky Survey (SDSS) quasars between redshifts of 1.5 and 3.5 in the 1.0–2.5 μm band. These spectra will cover critical diagnostic emission lines, such as Mg II, Hβ, and [O III], in each source. This project will more than double the existing inventory of near-infrared spectra of luminous quasars at these redshifts, including the era of fast quasar growth. Additional rest frame ultraviolet coverage of at least the C IV emission line is provided by the SDSS spectrum of each source. We will utilize the spectroscopic inventory to determine the most accurate and precise quasar black hole masses, accretion rates, and redshifts, and use the results to derive improved prescriptions for UV-based proxies for these parameters. The improved redshifts will establish velocities of quasar outflows that interact with the host galaxies, and will help constrain how imprecise distance estimates bias quasar clustering measurements. Furthermore, our measurements will facilitate a more complete understanding of how the rest-frame UV-optical spectral properties depend on redshift and luminosity, and test whether the physical properties of the quasar central engine evolve over cosmic time. We will make our data immediately available to the public, provide reduced spectra via a dedicated website, and produce a catalog of measurements and fundamental quasar properties.
318.10 – Steep Hard-X-ray Spectra Indicate Extremely High Accretion Rates in Weak Emission-Line Quasars
The present XMM-Newton imaging spectroscopy of ten weak emission-line quasars (WLQs) at z = 3.767, six of which are radio quiet and four which are radio intermediate. The new X-ray data enabled us to measure the hard-X-ray power-law photon index (Γ) in each source with relatively high accuracy. These measurements allowed us to confirm previous reports that WLQs have steeper X-ray spectra, therefore indicating higher accretion rates with respect to “typical” quasars. A comparison between the Γ values of our radio-quiet WLQs and those of a carefully-selected, uniform sample of 84 quasars shows that the first are significantly higher, at the × 30 level. Collectively, the four radio-intermediate WLQs have lower Γ values with respect to the six radio-quiet WLQs, as may be expected if the spectra of the first group are contaminated by X-ray emission from a jet. These results suggest that, in the absence of significant jet emission along our line of sight, WLQs constitute the extreme high end of the accretion rate distribution in quasars. We detect soft excess emission in our lowest-redshift radio-quiet WLQ, in agreement with previous findings suggesting that the prominence of this feature is associated with a high accretion rate. We have not detected signatures of Compton reflection, Fe Kα lines, or strong variability between two X-ray epochs in any of our WLQs.

Author(s): Andrea Marlar7, Ohad Shemmer7, Scott F Anderson8, W. Niel Brandt5, Aleksandar M. Diamond-Stanic4, Xiaohui Fan5, Bing Lu5, Richard Plotkin3, Gordon T. Richards2, Donald P. Schneider5, Jianfeng Wu9

318.11 – Examining an AGN Luminosity – SFR relation

319 – Cosmology and Large Scale Structure Poster Session

319.01 – Secular Extragalactic Parallax and Geometric Distances with Gaia Proper Motions
The motion of the Solar System with respect to the cosmic microwave background (CMB) rest frame creates a well measured dipole in the CMB, which corresponds to a linear solar velocity of about 78 AU/yr. This motion causes relatively nearby extragalactic objects to appear to move compared to more distant objects, an effect that can be measured in the proper motions of nearby galaxies. An object at 1 Mpc and perpendicular to the CMB apex will exhibit a secular parallax, observed as a proper motion, of 78 µas/yr. The relatively large peculiar motions of galaxies make the detection of secular parallax challenging for individual objects. Instead, a statistical parallax measurement can be made for a sample of objects with proper motions, where the global parallax signal is modeled as an E-mode dipole that diminishes linearly with distance. We present preliminary results of applying this model to a sample of nearby galaxies with Gaia proper motions to detect the statistical secular parallax signal. The statistical measurement can be used to calibrate the canonical cosmological “distance ladder.”

Author(s): Jennie Pain1, Jeremiah K. Darling1
Institution(s): 1. University of Colorado, Boulder

319.02 – Calibrating the Type Ia Supernova Distance Scale Using Surface Brightness Fluctuations
We have observed 20 supernova host galaxies with HST WFC3/IR in the F110W filter, and prepared the data for Surface Brightness Fluctuation (SBF) distance measurements. The purpose of this study is to determine if there are any discrepancies between the SBF distance scale and the type-Ia SNIa distance scale, for which local calibrators are scarce. We have now measured SBF magnitudes to all early-type galaxies that have hosted SN Ia within 80 Mpc for which SBF measurements are possible. SBF is the only distance measurement technique with
statistical uncertainties comparable to SN Ia that can be applied to galaxies out to 80 Mpc.

**Author(s):** Cicely Potter\(^5\), Joseph B. Jensen\(^5\), John Blakeslee\(^1\), Peter Milne\(^3\), Peter M. Garnavich\(^4\), Peter Brown\(^2\)

**Institution(s):** \(^1\) Herzberg Astrophysics, \(^2\) Texas A&M University, \(^3\) University of Arizona, \(^4\) University of Notre Dame, \(^5\) Utah Valley University

### 319.03 – Metallicity-Corrected Tip of the Red Giant Branch Densities to M66 and M96

We present distances to M66 and M96 obtained through measurements of the tip of the red giant branch (TRGB) in HST ACS/WFC images, and give details of our method. The TRGB can be difficult to determine in color-magnitude diagrams where it is not a hard, well-defined edge. We discuss our approach to this in our edge-detection algorithm. Furthermore, metals affect the magnitude of the TRGB as a function of color, creating a slope to the edge that has been dealt with in the past by applying a red color cut-off. We instead apply a metallicity correction to the data that removes this effect, increasing the number of useable stars and providing a more accurate distance measurement.

**Author(s):** Violet Mager\(^\text{-}2\), Barry F. Madore\(^1\), Wendy L. Friedman\(^1\)

**Institution(s):** \(^1\) Carnegie Observatories, \(^2\) Penn State Wilkes-Barre

### 319.04 – WFIRST: Science from Deep Field Surveys

WFIRST will enable deep field imaging across much larger areas than those previously obtained with Hubble, opening up completely new areas of parameter space for extragalactic deep fields including cosmology, supernova and galaxy evolution science. The instantaneous field of view of the Wide Field Instrument (WFI) is about 0.3 square degrees, which would for example yield an Ultra Deep Field (UDF) reaching similar depths at visible and near-infrared wavelengths to that obtained with Hubble, over an area about 100-200 times larger for a comparable investment in time. Moreover, wider fields on scales of 10-20 square degrees could achieve depths comparable to large HST surveys at medium depths such as GOODS and CANDELS, and would enable multi-epoch supernova science that could be matched in area to LSST Deep Drilling fields or other large survey areas. Such fields may benefit from being placed on locations in the sky that have ancillary multi-band imaging or spectroscopy from other facilities, from the ground or in space. The WFIRST Deep Fields Working Group has been examining the science considerations for various types of deep fields that may be obtained with WFIRST, and present here a summary of the various properties of different locations in the sky that may be considered for future deep fields with WFIRST.

**Author(s):** Anton M. Koekemoer\(^1\), Ryan Foley\(^2\)

**Institution(s):** \(^1\) STScI, \(^2\) UCSC

**Contributing team(s):** WFIRST Deep Field Working Group

### 319.05 – Characterizing the 21-cm absorption trough with pattern recognition and a numerical sampler

320 – White Dwarfs, Black Holes and Friends Poster Session

### 320.01 – Necroplanetology: Disrupted Planetary Material Transiting WD 1145+017

The WD 1145+017 system shows irregular transit features that are consistent with the tidal disruption of differentiated asteroids with bulk densities < 4 g cm\(^{-3}\) and bulk masses < 1021 kg. We use the open-source N-body code REBOUND to simulate this disruption with different internal structures: varying the core volume fraction, mantle/core density ratio, and the presence/absence of a thin low-density crust. We show that these parameters have observationally distinguishable effects on the transit light curve as the asteroid is disrupted and fit the simulation-generated lightcurves to data. We find that an asteroid with a low core fraction, low mantle/density ratio, and without a crust is most consistent with the A1 feature present for multiple weeks circa April 2017. This combination of observations and simulations to study the interior structure and chemistry of exoplanetary bodies via their destruction in action is an early example of necroplanetology, a field that will hopefully grow with the discovery of other systems like WD 1145+017.

**Author(s):** Girish Manideep Duvvuri\(^1\), Seth Redfield\(^3\), Dimitri Veras\(^2\)

**Institution(s):** \(^1\) CU-Boulder, \(^2\) University of Warwick, \(^3\) Wesleyan University
Supermassive black holes ( SMBHs) are known to commonly reside in the centers of large galaxies, but it is unclear whether they reside in smaller galaxies (M_\* < M_\*sun x 10^10). X-rays are the most efficient way to detect low-level accretion, and provide the best measurement of the occupation fraction. X-ray binaries can be nearly as bright as SMBHs that have sub-Eddington accretion rates. High-mass XRBs (HMXBs) are especially problematic because they can get brighter than low-mass XRBs. However, previous estimates of HMXB contamination (based on the optical continuum to get the fraction of HMXBs expected in the nucleus) may be too high. A better approach is to use FUV or H-alpha, which directly trace ongoing star formation. We did this in a sample of 30 late-type galaxies with Chandra data. We calculate the total Expected X-ray Luminosity from XRBs (L_x,E) for each sample galaxy using existing relationships between X-ray luminosity and SFR. We estimate the fraction of the stellar formation in the nucleus by measuring the fraction of nuclear UV or H-alpha light there (total SFR is from the far infrared). Our Galex data is scaled with a sample of 6 Swift UVOT galaxies to measure with the same aperture size that previous works have used in the B-band. We found that the mean L_x,E for Swift scaled FUV ratios is ~2.025 x 10^{36} and the mean L_x,E for H-alpha ratios is 7.693 x 10^{35}. These luminosities are 1.9 and 5 times smaller than B-band measured luminosities respectively. These results suggest that HMXBs do not contribute as much contamination in these galaxies as previously thought. Therefore, with a lower contamination, estimates of the occupation fraction from late-type galaxies are more reliable.

Author(s): Benjamin Dittenber1, Edmund J. Hodges-Kluck1, Elena Gallo1
Institution(s): 1. University of Michigan

Chandra Observations of the Eclipsing Wolf-Rayet Binary CQ Cep Over a Full Orbital Cycle

We present results of Chandra X-ray observations and simultaneous optical light curves of the short-period (1.64 d) eclipsing WN6+O9 binary system CQ Cep obtained in 2013 and 2017 covering a full binary orbit. Our primary objective was to compare the observed X-ray properties with colliding wind shock theory, which predicts that the hottest shock plasma (T > 20 MK) will form on or near the line-of-centers between the stars. Thus, X-ray variability is expected during eclipses when the hottest plasma is occulted. The X-ray spectrum is strikingly similar to apparently single WN6 stars such as WR 134 and spectral lines reveal plasma over a broad range of temperatures T ~ 4 - 40 MK. Both primary and secondary optical eclipses were clearly detected and provide an accurate orbital period determination (P = 1.6412 d). The X-ray emission remained remarkably steady throughout the orbit and statistical tests give a low probability of variability. The lack of significant X-ray variability during eclipses indicates that the X-ray emission is not confined along the line-of-centers but is extended on larger spatial scales, contrary to colliding wind predictions.

Author(s): Steve L. Skinner3, Manuel Guede4, Werner Schmutz2, Svetozar Zhekov1

Hydrodynamic Simulations of the Consequences of Accretion onto ONe White Dwarfs

Mass and luminosity variations of the white dwarf, combined with changes in the mass accretion rate and composition of the accreted material affect the evolution of the thermonuclear runaway (TNR) in the core material and subsequent novae. Here we highlight continued investigations of these effects on accreting Oxygen-Neon (ONe) white dwarfs. We now use the results of the multi-dimensional studies of TNRs in white dwarfs, accreting only solar matter, which show that sufficient core material is dredged-up during the TNR to agree with the measurements of ejecta abundances in classical nova explosions. Therefore, we first accrete solar material and follow the evolution until a TNR is ongoing. We then switch the composition to a mixture with either 25% core material or 50% core material (plus accreted material) and follow the resulting evolution of the TNR through peak nuclear burning and decline. We use our 1D, Lagrangian, hydrodynamic code: NOVA. We will report on the results of these new simulations and compare the ejecta abundances to those measured in pre-solar grains that are thought to arise from classical nova explosions. We will also compare these results to our companion studies, done in a similar fashion, where we have followed the consequences of accretion onto Carbon-Oxygen white dwarfs. This work was supported in part by NASA under the Astrophysics Theory Program grant 14-ATP14-0007 and the U.S. DOE under Contract No. DE-FG02-97ER41041. SS acknowledges partial support from NASA, NSF, and HST grants to ASU and WRH is supported by the U.S. Department of Energy, Office of Nuclear Physics.

Author(s): Sumner Starrfield1, Maitrayee Bose1, Christian Iliadis2, William Raphael Hix2, Charles E. Woodward3, Robert M. Wargner3, Jordi Jose4, Margarita Hernanz5, Wanda Feng1

Determining Mass-Loss Rates of Evolved Stars in the Galactic Bulge from Infrared Surveys

To investigate the relationship between mass loss from evolved stars and host galaxy metallicity, we are computing the dust mass loss budget due to red supergiant (RSG) and asymptotic giant branch (AGB) stars in the Galactic Bulge and comparing this result to that previously obtained for the Magellanic Clouds. We construct spectral energy distributions (SEDs) for our candidate RSG and AGB stars using observations from various infrared surveys, including the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE). Because Robitaille et al (2008, AJ, 136, 2413) have already identified Intrinsically Red Objects from the GLIMPSE I and II surveys, we use their method as a starting point and expand the study by using the GLIMPSE 3D survey. Because AGB stars can be variable, we also match the GLIMPSE I, II, and 3D sources to other surveys, such as DEEP GLIMPSE, WISE, VVV, and DENIS, in order to characterize the variability across the spectral energy distribution (SED) of each source. This allows us to determine the source's average SED over multiple epochs. We use extinction curves derived from Spitzer studies of
extinction in the Galaxy to determine the extinction corrections for our sample. To establish mass-loss rates of evolved stars in the Bulge, we use the Grid of Red supergiant and Asymptotic giant branch ModelIS (GRAMS) of dust-enshrouded evolved stars (2011, A&A, 532, A54; 2011, ApJ, 728, 93). This allows us to determine the total mass return to the Bulge from these stars. This work has been supported by NASA ADAP grant 80NSSC17K0057.

Author(s): Allyssa Riley3, Benjamin A. Sargent3, Sundar Srinivasan3, Margaret Meixner3, Joel H. Kastner2
Institution(s): 1. ASIAA, 2. Rochester Institute of Technology, 3. Space Telescope Science Institute

320.07 – A Search for Ultrafast Novae in M31
Numerous surveys in search of extragalactic novae have been completed over the last century. From Local Group surveys it has been estimated that the number of novae that occur in M31 is approximately 65 yr⁻¹ (Darnley et al. 2006), with a total of more than 1000 having been discovered over the past century. A fraction of these are recurrent novae that recur on the timescales of years to decades (Shafter et al. 2015).

Novae typically fade from view on timescales of weeks to months. However, Shara et al. (2017) present models that predict the existence of "ultrafast" novae that have two-magnitude decay times (t₂) of less than a day. The recent recurrent nova M31N 2008-12a has a t₂ time of ~2 days (e.g., Darnley et al. 2016). None faster than this have been seen in M31; however, most surveys of extragalactic novae use cadences of a day or longer, meaning such novae could be missed.

In October 2017 we completed a two-week search for ultrafast novae in M31 with the WIYN 0.9m telescope. The telescope’s Half-Degree Imager provided a field of view of a quarter square degree, which covers most of M31’s bulge and part of the disk. Weather hampered observations on some nights, but for most nights we were able to obtain multiple observations of M31 on a near hourly basis. We present the results of our search.

Author(s): Nicole Sola3, Travis A. Rector3, Allen W. Shafer2, Chuck Horst4, Amy Igarashi2, Martin Henze2, Catherine A. Pilachowski1
Institution(s): 1. Indiana University, 2. San Diego State University, 3. University of Alaska Anchorage

320.08 – A Twenty-Year Survey of Novae in M31
Numerous surveys of M31 in search of extragalactic nova have been completed over the last century, with a total of more than 1000 having been discovered during this time. From these surveys it has been estimated that the number of novae that occur in M31 is approximately 65 yr⁻¹ (Darnley et al. 2006). A fraction of these are recurrent novae that recur on the timescales of years to decades (Shafter et al. 2015).

From 1997 to 2017 we completed observations of M31 with the KPNO/WIYN 0.9-meter telescope, which offers a wide field of view suitable for surveying nearly all of the bulge and much of the disk of M31. Observations were completed in Hα so as to better detect novae in the bulge of the galaxy, where most novae reside. Our survey achieves a limiting absolute magnitude per epoch of M_Hα ~ 7.5 mag, which prior M31 nova surveys in Hα (e.g., Ciardullo et al. 1987; Shafer & Irby 2001) have shown to be sufficiently deep to detect a typical nova several months after eruption. By completing nearly all of the observations with the same telescope, cameras, and filters we were able to obtain a remarkably consistent dataset.

Our survey offers several benefits as compared to prior surveys. Nearly 200 epochs of observations were completed during the survey period. Observations were typically completed on a monthly basis; although on several occasions we completed weekly and nightly observations to search for novae with faster decay rates. Thus we were sensitive to most of the novae that erupted in M31 during the survey period.

Over twenty years we detected 316 novae. Our survey found 85% of the novae in M31 that were reported by other surveys completed during the same time range and in the same survey area as ours (Pietsch et al. 2007). We also discovered 39 novae that were not found by other surveys. We present the complete catalog of novae from our survey, along with example light curves. Among other uses, our catalog will be useful for improving estimates of nova rate in M31. We also identify 72 standard stars within the survey area that will be useful for future surveys.

Author(s): Hannah Crayton3, Travis A. Rector3, Matthew J. Walentosky3, Allen W. Shafer2, Stephanie Lauber2, Catherine A. Pilachowski1
Institution(s): 1. Indiana University, 2. San Diego State University, 3. University of Alaska Anchorage
Contributing team(s): RBSE Nova Search Team

320.09 – HST FUV/NUV Photometry of the Putative Binary Companion to the SN 1993J Progenitor
A previous analysis of HST/COS spectra from 2012 revealed an FUV excess consistent with the presence of the hypothetical B-star companion to the SN 1993J progenitor. The spectrum, however, had low signal-to-noise and was blended with several other nearby stars within the 2.5 arcsec COS aperture. Since that time, the SN has sufficiently faded allowing for more accurate photometry to be performed. Here we present follow-up HST FUV/NUV imaging using the F410LP filter on ACS/SBC and the F218W, F275W, and F336W filters on WFC3/UVIS. This photometry isolates the UV flux from only the putative companion. We will discuss whether this new evidence removes all ambiguity about the nature of the companion once and for all.

Author(s): Nathan Miles3, Orr Fox3, K. Azalee Bostroem6, Wei Kang Zheng5, Melissa Graham9, Schuyler D. Van Dyk1, Alexei V. Filippenko5, Thomas Matheson4, Vikram Dwarkadas8, Claes Fransson4, Nathan Smith7, Thomas Brink5

320.10 – Fevers and Chills: Separating thermal and synchrotron components in SNR spectra
Spatially-resolved spectroscopy is an extremely powerful tool in X-ray analysis of extended sources, but can be computationally difficult if a source exhibits complex morphology. For example, high-resolution Chandra data of bright Galactic supernova remnants (Cas A, Tycho, etc.) allow extractions of high-quality spectra from tens to hundreds of thousands of regions, providing a rich laboratory for localizing emission from processes such as thermal line emission, bremsstrahlung, and synchrotron. This soft-band analysis informs our understanding of the typically nonthermal hard X-ray emission observed with other lower-resolution instruments. The analysis is complicated by both projection effects and the presence of multiple emission mechanisms in some regions. In particular, identifying regions with significant nonthermal emission is critical to understanding acceleration processes in remnants. Fitting tens of thousands of regions with complex, multi-component models can be time-consuming and involve so many free parameters that little constraint can be placed on the values. Previous work by Stage & Allen (’06, ’07, ’11) on Cas A used a technique to identify regions dominated by the highest-cutoff synchrotron emission by fitting with a simple thermal emission model and identifying regions with anomalously high apparent temperatures (caused by presence of the high-energy tail of the synchrotron emission component). Here, we present a similar technique. We verify the previous approach and, more importantly, expand it to include a method to identify regions containing strong lower-cutoff synchrotron radiation. Such regions might be associated with the reverse-shock of a supernova. Identification of a nonthermal electron population in the interior of an SNR would have
significant implications for the energy balance and emission mechanisms producing the high-energy (> 10 keV) spectrum.

Author(s): Emily Elizabeth Fedor¹, Hyourin Martina-Hood¹, Michael D. Stage¹
Institution(s): 1. Amherst College

322 – AGN, QAOs and Blazars iPoster Session

322.01 – Characterizing the evolution of WISE-selected obscured and unobscured quasars using HOD models.
Large-area imaging surveys in the infrared are now beginning to unlock the links between the activity of supermassive black holes and the cosmic evolution of dark matter halos during the significant times when black hole growth is enshrouded in dust. With data from the Wide-Field Infrared Survey Explorer (WISE) and complementary optical photometry, we construct samples of nearly half-a-million obscured and unobscured quasars around redshift 1. We study the dark matter halos of these populations using both angular autocorrelation functions and CMB lensing cross-corrrelations, carefully characterizing the redshift distribution of the obscured quasar sample using cross-correlations. Independent of our measurement technique, we find that obscured quasars occupy dark matter halos a few times more massive than their unobscured counterparts, despite being matched in luminosity at 12 and 22 microns. Modeling the two-point correlation function using a four-parameter Halo Occupation Distribution (HOD) formalism, we determine that purely optically selected quasars reside in dark matter halos that are about half the mass of WISE-selected obscured quasars, and that satellite fractions are somewhat larger for obscured quasars. We investigate scenarios such as merger-driven fueling and Eddington-dependent obscuration to explore what combinations of physical effects can reproduce our observed halo mass measurements. This work was, in part, supported by NASA ADAP award NNX16AN48G.

Author(s): Adam D. Myers³, Michael A. DiPompeo¹, Kaustav Mitra², Ryan C. Hickox³, Suchetana Chatterjee₂, Kelly Whalen¹
Institution(s): 1. Dartmouth College, 2. Presidency University, 3. University of Wyoming

322.02 – What drives the evolution of Luminous Compact Blue Galaxies in Clusters vs. the Field?
Low-mass dwarf ellipticals are the most numerous members of present-day galaxy clusters, but the progenitors of this dominant population remain unclear. A prime candidate is the class of objects known as Luminous Compact Blue Galaxies (LCBGs), common in intermediate-redshift clusters but virtually extinct today. Recent cosmological simulations suggest that present-day dwarf galaxies begin as irregular field galaxies, undergo an environmentally-driven starburst phase as they enter the cluster, and stop forming stars earlier than their counterparts in the field. This model predicts that cluster dwarfs should have lower stellar mass per unit dynamical mass than their counterparts in the field. We are undertaking a two-pronged archival research program to test this key prediction using the combination of precision photometry from space and high-quality spectroscopy. First, we are combining optical HST/ACS imaging of five z=0.55 clusters (including two HST Frontier Fields) with Spitzer IR imaging and publicly-released Keck/DEIMOS spectroscopy to measure stellar-to-dynamical-mass ratios for a large sample of cluster LCBGs. Second, we are exploiting a new catalog of LCBGs in the COSMOS field to gather corresponding data for a significant sample of field LCBGs. By comparing mass ratios from these datasets, we aim to test theoretical predictions and determine the primary physical driver of cluster dwarf-galaxy evolution.

Author(s): Gregory D. Wirth¹, Matthew A. Bershady³, Steven M Crawford⁴, Lucas Hunt², Daniel J. Pisano⁵, Solohery M Randriamampandry³

322.03 – Investigating the Fraction of Radio-Loud Quasars with High Velocity Broad Emission Lines
Quasars show a bimodal distribution in their radio emission, with some having powerful radio-emitting jets (radio-loud), and most having weak or no jets (radio-quiet). Surveys have shown around 10% of of quasars have detectable radio emissions. These quasars are called radio-loud. Several multiwavelength studies have shown that radio-loud quasars have different properties than radio-quiet quasars. This fraction of radio-loud quasars to radio-quiet quasars has been assumed to be constant across all parameter space. In this study, we breakdown the parameter space with respect to the increasing velocity dispersion of broad emission lines. Our sample has been drawn from 2011 Shen et al. catalog of more than 100,000 quasars. In this study, we demonstrate that this fraction varies with respect to the increasing velocity dispersion (FWHM) of broad emission lines. We compare three different emission lines: H-Beta, MgII, and CIV. We observe with increasing FWHM of these three emission lines, fraction of radio-loud quasars within the subset increases. This poster presents our initial results into investigating whether the fraction of RL quasars remains 10% in different parameter space.

Author(s): Anirban Bhattacharjee¹, Miranda Gilbert¹, Michael S. Brotherton²
Institution(s): 1. Sul Ross State University, 2. University of Wyoming
Contributing team(s): anirban bhattacharjee

322.04 – Search for X-ray jets from high redshift radio sources.
We are conducting a Chandra “snapshot” survey of 14 radio quasars at redshifts z>3. These are selected to have one sided, arc-sec scale structure, either a jet or lobe, and come from a complete, objectively-defined sample of sources with radio flux density > 70 mJy, and with a spectroscopic redshift from the SDSS. Our objectives are to find X-ray emitting jets, compare the X-ray and radio morphology, and detect X-ray emission arising from inverse Compton scattering of the cosmic microwave background even for those cases where the radio emission is no longer detectable. For this meeting, we expect 5 of the 14 sources to have been observed.

Author(s): Daniel A. Schwartz², Teddy Cheung⁵, Doug Gobellie⁷, Herman L. Marshall⁴, Giulia Migliorisi³, Aneta Siemiginowska², John F. C. Wardle¹, Diana M Worrall⁵, Mark Birkinshaw⁶
Institution(s): 1. Brindeis University, 2. Harvard-Smithsonian, CfA, 3. Laboratoire AIM, 4. MIT Kavli Institute, 5. Naval Research Laboratory, 6. Physics Department, University of Bristol, 7. University of Rhode Island

322.05 – Monitoring AGNs with Hbeta Asymmetry with the Wyoming Infra-Red Observatory
We present preliminary results from two seasons of reverberation mapping of AGNs using the optical longslit spectrograph on the 2.3 meter WIRO telescope. The majority of the sample is part of our “Monitoring AGNs with Hbeta Asymmetry” project, also
known as MAHA, which targets rarer AGNs with extremely asymmetric profiles that may provide new insights into the full diversity of size and structure of the broad-line region (BLR). Our hundreds of nights of telescope time provide dozens of epochs of spectra for approximately two dozen objects. Notably we find that many AGNs with broader asymmetric Hbeta emission lines possess time lags significantly shorter than expected for their luminosity in comparison to the majority of AGNs reverberation mapped.

Author(s): Michael S. Brotherton3, Pu Du1, Jian-Min Wang1, Kai Wang2, Zhengpeng Huang1, Chen Hu1, Yan-rong Li1, David H. Kasper3, William T. Chick3, My L. Nguyen3, Jaya Maithil3, Derek Hand3, Jin-Ming Bai4, Luis Ho2

Institution(s): 1. Institute of High Energy Physics, 2. Kavli Institute of Astronomy and Astrophysics, Peking University, 3. Univ. of Wyoming, 4. Yunnan Observatory

322.06 – A Very Large Array Survey of Polar BAL Quasar Candidates

Polar broad absorption line quasars possess flat radio spectra and jets seen at small angles to the line of sight. Using the VLA we observed twelve polar broad absorption line quasar candidates at L (1.5GHz), C (4.5-5.5GHz), and X (8.5-9.5GHz) bands, and found that their cores display flat spectra. Compared to previous observations in the NVSS and First surveys, the peak flux densities all show significant variation $\sigma_{\text{var}} > 3$, and brightness temperatures $T_b > 10^{12}$K. Based on these findings, our quasars have the properties expected for objects that possess jets seen nearly pole on.

Author(s): Kianna Alexandra Olson2, Michael S. Brotherton2, Michael DiPompeo1, Jaya Maithil2

Institution(s): 1. Dartmouth College, 2. University of Wyoming

322.07 – EVLA observations of radio-loud quasars selected to study radio orientation

We present preliminary work to develop an unbiased sample of radio-loud quasars to test orientation indicators. We have obtained radio data of 147 radio-loud quasars using EVLA at 10 GHz and with the A-array. With this high-resolution data we have measured the uncontaminated core flux density to determine orientation indicators based on radio core dominance. The radio cores of quasars have a flat spectrum over a broad range of frequencies, so we expect that the core flux density at the FIRST and the observed frequencies should be the same in the absence of variability. Jackson & Brown (2012) pointed out that the survey measurements of core flux density, like FIRST, often don’t have the spatial resolution to distinguish cores from extended emission. Our measurements show that at FIRST spatial resolution, core flux measurements are indeed systematically high. Our results establish that orientation studies need high-resolution radio data as compared to survey data, and that the optical emission is a better normalization than the extended radio emission for a core dominance parameter to track orientation.

Author(s): Jaya Maithil9, Michael S. Brotherton6, Jessie Runnoe4, John F. C. Wardle1, Michael DiPompeo2, Carlos De Breuck3, Beverley J. Wills5


322.08 – Stochastic External Accretion and Asymmetric Outflows in NGC 4388

We present here our findings on the Seyfert 2 galaxy, NGC 4388, one of the 40 active galactic nuclei (AGN) studied in the Keck/OSIRIS nearby AGN survey (KONA). NGC 4388 is located in the heart of the dense Virgo cluster, making it susceptible to interactions with neighboring galaxies and the intra-cluster medium. Using near-Infrared Adaptive-Optics Integral-Field Spectroscopy, we examined the two-dimensional spatial distribution and kinematics of the molecular and ionized gas in NGC 4388. We found that the nearly edge-on galaxy exhibits an asymmetric outflow with signatures of external accretion feeding the AGN. To the southwest an outflow of ionized gas is extended along a position angle (PA) of 35 degrees and to the northeast a position angle between 30 to 60 degrees. This indicates a misalignment between the AGN torus and the galactic plane. As a result of the outflow in the southwest, molecular gas in the disk has been pushed to the west. Examining the molecular gas further led us to determine the presence of a warped disk surrounding the nucleus. In comparing our near-Infrared kinematic results to studies in different multi-wavelength datasets, we found evidence for a past minor merger event that drives gas inward to feed the AGN.

Author(s): Skylar Shaver3, Francisco Mueller Sanchez3, Matthew Arnold Malkan2, Erin K. S. Hicks1


323 – White Dwarfs, Black Holes, Supernovae and Friends iPoster Session

323.01 – The Evolution of NR TrA (Nova TrA 2008) from 2008 through 2017

The classical nova NR TrA was discovered as an O-type optically-thick classical nova. There is no evidence that it formed dust. Within four years the envelope became sufficiently thin to reveal the nearly edge on galaxy exhibits an asymmetric outflow for a core dominance parameter to track orientation.

Author(s): Frederick M. Walter3, Vadim Burwitz2, Stella Kafka1

Institution(s): 1. AAVSO, 2. MPE, 3. Stony Brook University

323.02 – Signatures of Synchrotron: Low-cutoff X-ray emission and the hard X-ray spectrum of Cas A

In soft X-rays, bright, young Galactic remnants (Cas A, Kepler, Tycho, etc.) present thermal line emission and bremsstrahlung from ejecta, and synchrotron radiation from the shocks. Their hard X-ray spectra tend to be dominated by power-law sources. However, it can be non-trivial to discriminate between contributions from processes such as synchrotron and bremsstrahlung from nonthermally accelerated electrons, even though the energies of the electrons producing this radiation may be very different. Spatially-resolved spectroscopic analysis of 0.5-10 keV observations with, e.g., Chandra can provide leverage in identifying the processes and their locations. Previously, Stage & Allen (2006), Allen & Stage (2007) and Stage & Allen (2011) identified regions characterized by high-cutoff synchrotron radiation. Extrapolating synchrotron model fits to the emission in the Chandra band, they estimated the synchrotron contribution to the hard X-ray spectrum at about one-third the observed flux, fitting the balance with nonthermal bremsstrahlung emission produced by nonthermal electrons in the ejecta. Although it is unlikely this analysis missed regions of the highest-cutoff synchrotron emission, which supplies the bulk of the synchrotron above 15 keV, it may have missed regions of lower-cutoff emission, especially if they are near bright ejecta and the reverse shock. These regions cannot explain the emission at the highest energies (~50 keV), but may make significant contributions to the hard spectrum at lower energies (~10 keV). Using the technique described in Fedor, Martina-Hood & Stage (this meeting), we revisit the analysis to include regions that may be dominated by low-cutoff synchrotron, located in the interior of the remnant, and/or correlated with the reverse shock. Identifying X-ray emission from accelerated electrons associated with the reverse-
shock would have important implications for synchrotron and non-thermal bremsstrahlung radiation above the 10 keV.

Author(s): Michael D. Stage1, Emily Elizabeth Fedor1, Hyourin Martina-Hood1
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323.03 – The Expanding Bipolar Conic Shell of the Symbiotic Star AG Peg
Symbiotic stars are the most interesting since some systems are believed to host the most massive white dwarf, like SN Ia progenitors. Most recently, Lee and Hyung (2018, LH18) proposed a bipolar conic shell structure for the observed high expansion Hα and Hβ line profiles and other double peak lines observed in 1998 September (phase φ = 10.24): the physical conditions for the white dwarf luminosity and the ionized HII zone, responsible for double Gaussian optical lines including Balmer and Lyman line fluxes, were taken from the P-I model with gas density, $n_H = 10^{9.85}$ cm$^{-3}$, while the column density for the scattering neutral zone was derived from the broader line components based on the result by Monte Carlo simulations. In this investigation, we examined whether the expanding shells of the bipolar conical geometry as proposed by LH18 would be able to form the other Hα and Hβ line profiles observed in other phases, φ = 11.56 and 11.98 (in 2001 August and 2002 August). We look into the kinematical property of the bipolar conic shell structure responsible for the HII and HI zones and then we discuss the secular variation of the broad line feature and the origin of the bipolar cone, i.e., part of a common envelope formed through the mass inflows from the giant star.

Author(s): Seong-Jae Lee1, Siek Hyung1
Institution(s): 1. Chungbuk National University

323.04 – Predicting the next local supernova
It has been over 31 years since Supernova 1987A, and we have learned many things from the neutrinos, light curve, evolving spectrum including the “Bochum Event” at day 19.2, the associated “Bright Spot” or “Mystery Spot,” and its motion away from the position of the progenitor, SK –69°202, the mixing, rings, X- and gamma-rays, polarization, and the 467.5 Hz pulsation and its associated ~1,000 s precession (or the lack of any strongly magnetized remnant). Finally, our understanding of this event has progressed to the point where we have a time interval of a few months during which we can predict which supergiant star in our local neighborhood out to 5 Megaparsecs will be the next to die in a supernova explosion.

Author(s): John Middleditch1
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323.05 – Nearby Type Ia Supernova Follow-up at the Thacher Observatory
Type Ia supernovae (SN Ia) provide an effective way to study the expansion of the universe through analyses of their photometry and spectroscopy. The interpretation of high-redshift SN Ia is dependent on accurate characterization of nearby, low-redshift targets. To help build up samples of nearby SN Ia, the Thacher Observatory has begun a photometric follow-up program in 4 photometric bands. Here we present the observations and analysis of multi-band photometry for several recent supernovae as well as FLOYDS spectra from the Las Cumbres Observatory.

Author(s): Jonathan Swift1, Katie O’Neill1, Charles Kilpatrick1, Kyan Foley2
Institution(s): 1. Thacher School, 2. University of California, Santa Cruz

323.06 – SiO maser emission as a density tracer of circumstellar envelopes
The circumstellar envelopes (CSEs) of evolved stars offer a method to construct a sample of point-masses along the full Galactic plane, which can be used to test models of the gravitational potential. In the CSEs of red giants, SiO maser emission is frequently observed at 43 and 86 GHz, providing line-of-sight velocities. The Bulge Asymmetries and Dynamical Evolution (BAADE) project aims to explore the complex structure of the inner Galaxy and Galactic Bulge, by observing 43 GHz SiO at the Very Large Array and 86 GHz SiO at the Atacama Large Millimeter/submillimeter Array, with an expected final sample of about 20,000 line-of-sight velocities and positions. We observed the 43 GHz and 86 GHz transitions near-simultaneously in a subsample of the sources using the Australia Telescope Compact Array and found that on average the 43 GHz $v=1$ line is 1.3 times stronger than the 86 GHz $v=1$ line. The presence of a detectable 43 GHz $v=3$ line alters the statistics, consistent with the SiO masers displaying 43 GHz $v=3$ emission arising in a denser regime in the circumstellar shell compared to those without. Comparing our results with radiative models implies that the 43 GHz $v=3$ line is a tracer of density variations caused by stellar pulsations. We will discuss these results in the context of the BAADE project.

Author(s): Michael Stroh2, Ylva Pihlstrom3, Lorant Sijouwerman1
Institution(s): 1. NRAO, 2. University of New Mexico

323.07 – Exploring Pulsars with Polestar
An X-ray pulsar (XRP) is a highly-magnetized neutron star (NS) that rotates while emitting beams of X-ray radiation produced primarily in the vicinity of its magnetic poles. If these beams happen to cross our line of sight and the NS’s spin and magnetic axes are not aligned, then our telescopes detect it as a periodically pulsating source. With the introduction of a new class of orbit-based observatories over the last quarter of a century the field of X-ray pulsar astronomy has seen an influx of high-resolution data. This windfall demands new models of pulsar behavior and emission geometry be created and subsequently fit to this high-quality data.

We have written a model (Polestar) in Python 2.7.6 that mathematically represents a simplified XRP. The code has ten different, tunable Gaussian optical parameters that can be individually incorporated or suppressed. Any given XRP has a unique pulse profile which is often energy-dependent, and changes with different luminosity states. A change in luminosity coincides with a change in the system (e.g. a periodic Type-1 outburst is triggered following periastron passage, or the orientation of the accretion disk around the donor star has changed), and as such an increase in luminosity tends to produce an increase in complexity of the accompanying pulse profile. If a particular source in a low-luminosity state can be fit well with Polestar incorporating only a few parameters then an underlying geometry may be inferred. Further, if profiles from the same source in different luminosity states can be fit with the addition of only one or two additional parameters it will serve to further solidify current XRP theory (e.g. the emergence of fan-like emission patterns, or the vertical growth of the accretion column).

Our initial fitting campaign was directed at the ~ 100 XRPs in the Small Magellanic Cloud. Polestar also includes an interactive slider GUI that allows the user to see in real time how changing the various profiles alter the resulting profile (an ideal application for an iPoster). Polestar will be freely available on the web to the general astrophysics community and the hope is that in the future it will be used to fit pulse profiles from any XRP in the sky.

Author(s): Rigel Cappallo1, Silas Laycock1, Dimitris Christodoulou1
Institution(s): 1. University of Massachusetts Lowell
Contributing team(s): University of Southampton, Harvard CFA, University of Crete, NASA

323.08 – A Temporal Correlation in Quiescent Gamma-Ray Burst Prompt Emission: Evidence for Progenitor Memory
In spite of the insight gained into the nature of the Gamma-Ray Bursts (GRB) from early and late-time X-Ray observations in the Swift era, GRB prompt emission continues to provide clues and new insight into the activity of the central engine. A
emissions and quiet time durations. This variability allows us to extrapolate that the central engine is constantly active.

Author(s): Thomas L. Patton, Timothy Giblin, Jon E. Hakkila

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324 – Extragalactic Topics iPoster Session

324.01 – Testing the uniqueness of mass models using gravitational lensing

The positions of images produced by the gravitational lensing of background-sources provide insight to lens-galaxy mass distributions. Simple elliptical mass density profiles do not agree well with observations of the population of known quads. It has been shown that the most promising way to reconcile this discrepancy is via perturbations away from purely elliptical mass profiles by assuming two super-imposed, somewhat misaligned mass distributions: one is dark matter (DM), the other is a stellal distribution. In this work, we investigate if mass modelling of individual lenses can reveal if the lenses have this type of complex structure, or simpler elliptical structure. In other words, we test mass model uniqueness, or how well an extended source lensed by a non-trivial mass distribution can be modeled by a simple elliptical mass profile. We used the publicly-available lensing software, Lensmodel, to generate and numerically model gravitational lenses and “observed” image positions. We then compared “observed” and modeled image positions via root mean square (RMS) of their difference. We report that, in most cases, the RMS is ≤0.05″ when averaged over an extended source. Thus, we show it is possible to fit a smooth mass model to a system that contains a stellar-component with varying levels of misalignment with a DM-component, and hence mass modelling cannot differentiate between simple elliptical versus more complex lenses.

Author(s): Levi Walls, Liliya L.R. Williams
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324.02 – Development of High Frequency Transition-Edge-Sensor Polarimeters for Next Generation Cosmic Microwave Background Experiments and Galactic Foreground Measurements

Observations of the cosmic microwave background (CMB) provide a powerful tool for probing the earliest moments of the universe and therefore have the potential to transform our understanding of cosmology. In particular, precision measurements of its polarization can reveal the existence of gravitational waves produced during cosmic inflation. However, these observations are complicated by the presence of astrophysical foregrounds, which may be separated by using broad frequency coverage, as the spectral energy distribution between foregrounds and the CMB is distinct. For this purpose, we are developing large-bandwidth, feedhorn-coupled transition-edge-sensor (TES) arrays that couple polarized light from waveguide to superconducting microstrip by use of a symmetric, planar orthomode transducer (OMT). In this work, we describe two types of pixels, an ultra-high frequency (UHF) design, which operates from 195 GHz-315 GHz, and an extended ultra-high frequency (UHFF++) design, which operates from 195 GHz-420 GHz, being developed for next generation CMB experiments that will come online in the next decade, such as CCAT-prime and the Simons Observatory. We present the designs, simulation results, fabrication, and preliminary measurements of these prototype pixels.

Author(s): Samantha Walker, Carlos E. Sierra, Jason Edward Austermann, James Beall, Dan Becker, Bradley Dober, Shannon Duff, Gene Hilton, Johannes Hubmayr, Jeffrey L. Van Lanen, Jeff McMahon, Sara M. Simon, Joel Ullom, Michael R. Vissers
Contributing team(s): NIST Quantum Sensors Group

324.03 – Large-Scale Structure Behind The Milky Way with ALFAZOA

The region of the sky behind the Milky Way (the Zone of Avoidance; ZOA) is not well studied due to high obscuration from gas and dust in our galaxy as well as stellar confusion, which results in low detection rate of galaxies in this region. Because of this, little is known about the distribution of galaxies in the ZOA, and other all sky redshift surveys have incomplete maps (e.g. the 2MASS Redshift survey in NIR has a gap of 5-8 deg around the Galactic plane). There is still controversy about the dipole anisotropy calculated from the comparison between the CMB and galaxy and redshift surveys, in part due to the incomplete sky mapping and redshift depth of these surveys. Fortunately, there is no ZOA at radio wavelengths because such wavelengths can pass unimpeded through dust and are not affected by stellar confusion. Therefore, we can detect and make a map of the distribution of obscured galaxies that contain the 21cm neutral hydrogen emission line, and trace the large-scale structure across the Galactic plane. The AreCibo L-Band Feed Array Zone of Avoidance (ALFAZOA) survey is a blind HI survey for galaxies behind the Milky Way that covers more than 1000 square degrees of the sky, conducted in two phases: shallow (completed) and deep (ongoing). We show the results of the finished shallow phase of the survey, which mapped a region between the galactic longitude l=30-75 deg, and latitude b <10 deg, and detected 418 galaxies to about 12,000 km/s, including galaxy properties and mapped large-scale structure. We do the same for new results from the deep phase, which is ongoing and covers 30 < l < 75 deg and b < |2| deg for the inner galaxy and 175 < l < 207 deg, with -2 < b < -1 for the outer galaxy.

Author(s): Monica Sanchez Barrantes, Patricia A. Henning, Emmanuel Momjian, Travis McIntyre, Robert F. Minchin
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324.04 – Gravitational Lensing 2.0

Weak lensing analyses use the image---the intensity field---of a distant galaxy to infer gravitational effects on that line of sight. What if we analyze the velocity field instead? We show that lensing imprints much more information onto a highly ordered velocity field, such as that of a rotating disk galaxy, than onto an intensity field. This is because shuffling intensity pixels yields a post-lensed image quite similar to an unlensed galaxy with a different orientation, a problem known as "shape noise." We show that velocity field analysis can eliminate shape noise and yield much more precise lensing constraints. Furthermore, convergence as well as shear can be constrained using the same target, and there is no need to assume the weak lensing limit of small convergence. We present Fisher matrix forecasts of the precision achievable with this method. Velocity field observations are expensive, so we derive guidelines for choosing suitable
targets by exploring how precision varies with source parameters such as inclination angle and redshift. Finally, we present simulations that support our Fisher matrix forecasts.

**Author(s):** David M. Wittman¹, Bryant Benson¹
**Institution(s):** 1. UC, Davis

### 324.05 – Spectroscopic Confirmation of Five Galaxy Clusters at z > 1.25 in the 2500 deg⁻² SPT-SZ Survey

We present spectroscopic confirmation of 5 galaxy clusters at 1.25 < z < 1.5, discovered in the 2500 deg² South Pole Telescope Sunyaev-Zel'dovich (SPT-SZ) survey. These clusters, taken from a nearly redshift-independent mass-limited sample of clusters, have multi-wavelength follow-up imaging data from the X-ray to the near-IR, and currently form the most homogenous massive high-redshift cluster sample in existence. We briefly describe the analysis pipeline that allowed us to identify the clusters, describe the properties of these clusters, and discussing the implications for the development of cluster number counts and galaxy cluster evolution.

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**Institution(s):** 1. Argonne National Laboratory, 2. Massachusetts Institute of Technology, 3. The University of Chicago
**Contributing team(s):** South Pole Telescope (SPT) Collaboration

### 324.06 – CGM Evolution of a Simulated Dwarf Galaxy

The circumgalactic medium (CGM), which is fed by galactic outflows, is intrinsically connected to star formation and galactic evolution. We followed the evolution of the CGM of a simulated dwarf galaxy of mass 4.75 x 10¹⁰ solar masses, through five timesteps corresponding to z = 3, 2, 1, 0.5, 0.15. The simulation includes metal line cooling, metal diffusion, and supernova feedback, and the resulting galaxy has a realistic stellar mass and metallicity. We measured the surface densities of HI, CIV and OVI in the CGM gas composition and analyzed their trends in relation to the galaxy’s evolution. Additionally, we created mock absorption line spectra, which we used to find the mean equivalent width for sight lines spaced 0.1R/Rvir apart. From this analysis, we saw there was high metallicity at large radii, and over time the CGM cooled and became more ordered. We note the impact of a merger with a smaller galaxy at z = 0.5. We compare these results to observations.

**Author(s):** Patrick Sheehan-Klenk¹, Charlotte Christensen¹
**Institution(s):** 1. Grinnell College

### 325 – Stellar Topics iPoster Session

#### 325.01 – SOFIA EXES Observations of Herschel’s Garnet Star and the two α Red Supergiants

We report EXES Cycle 4 and 5 observations of M supergiants, with high spectral resolution (R > 50,000), and obtained from NASA-DLR SOFIA.

Emission profiles from Herschel's Garnet Star (μ Cephei: M2 Ia) show distinct structure and asymmetry in the [S I] 25.25 micron and [Fe II] 25.99 micron lines. These profiles are unlike the remarkably symmetric [Fe II] profile observed from Betelgeuse (α Orionis: M2 IIa) at R=65,000. These diagnostics both arise from upper energy levels with E_up = 550 K and they probe the inner circumstellar envelope. The flux ratios of [S I]/[Fe II] are very different for μ Cep, α Ori, and Antares (α Scorpii: M1.5 Iab), which is thought to have been produced by a thermal pulse event ~2200 years ago. We observed R Scl with the Faint Object InfraRed CAMera for the SOFIA Telescope (FORCAST) at 19.7, 25.2, 31.5, 34.8, and 37.1 μm to study its circumstellar dust emission. Maps of the infrared emission were used to examine the morphology of the shell

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**Institution(s):** 1. Dalhousie University, 2. UC Davis, 3. University of Colorado, 4. USRA/SOFIA, NASA Ames Research Center, 5. Villanova University
**Contributing team(s):** EXES Instrument Team

#### 325.02 – Constraining the Post-Thermal Pulse Mass-Loss History of R Scl with SOFIA/FORCAST

R Sculptoris (R Scl) is a nearby (~370 pc) carbon star with a massive circumstellar shell (M_shell~7×10⁻³ M⊙) which is thought to have been produced by a thermal pulse event ~2200 years ago. We observed R Scl with the Faint Object InfraRed CAMera for the SOFIA Telescope (FORCAST) at 19.7, 25.2, 31.5, 34.8, and 37.1 μm to study its circumstellar dust emission. Maps of the infrared emission were used to examine the morphology of the shell...
and temperature structure of the spatially extended dust emission. We used the radiative transfer code DUSTY
to fit the radial density profile of the circumstellar material, and find that a
generically thin dust shell cannot reproduce the observed emission. Instead, a second dust component is needed to model the emission. This component, which lies interior to the dust shell, traces the post-thermal pulse mass loss of R ScI and is indicative of a slow decline in the star's mass loss over thousands of years. This result is at odds with 'classical' thermal pulse models but is consistent with earlier observations of molecular gas in R ScI's circumstellar environment.

Author(s): Matthew Hanks3, Terry Herter3, matthias maercker2, Ryan M. Laul1, Greg Sloan4

325.03 – Using RADMC-3D to model the radiative transfer of spectral lines in protoplanetary disks and envelopes
Protoplanetary disks are the birthplaces of planets in our universe. Observations of these disks with radio telescopes like the Atacama Large Millimeter Array (ALMA) offer great insight into the star and planet formation process. Comparing theories of formation with observations requires tracing the energy transfer via electromagnetic radiation, known as radiative transfer. To determine the temperature distribution of circumstellar material, a Monte Carlo code (Whitney et al. [1]) was used to perform the radiative transfer through dust. The goal of this research is to utilize RADMC-3D [2] to handle the spectral line radiative transfer computations. An existing model of a rotating ring was expanded to include emission from the C18O isotopologue of carbon monoxide using data from the Leiden Atomic and Molecular Database (LAMDA). This feature of our model compliments ALMA's ability to measure C18O line emission, a proxy for disk rotation. In addition to modeling gas in the protoplanetary disk, dust also plays an important role. The generic description of absorption and scattering for dust provided by RADMC-3D was changed in favor of a more physically-realistic description with OH5 grains. This description is more appropriate in high-density regions of the envelope around a protostar. Further improvements, such as consideration for the finite resolution of observations, have been implemented. The task at present is to compare our model with observations of protoplanetary systems like L1527. Some results of these comparisons will be presented.


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Institution(s): 1. California State University Los Angeles

325.04 – Multiband Lightcurve of Tabby's Star: Observations and Modeling
Since March 2017, The Thacher Observatory in California has been monitoring changes in brightness of KIC 8462892 (Tabby’s Star), an F-type main sequence star whose irregular dimming behavior was first discovered by Tabetha Boyajian by examining Kepler data. We obtained over 20k observations over 135 nights in 2017 in 4 photometric bands, and detected 4 dip events greater than 1%. The relative magnitude of each dip compared across our 4 different photometric bands provides critical information regarding the nature of the obscuring material, and we present a preliminary analysis of these events. The Thacher Observatory is continuing its monitoring of Tabby’s Star in 2018.

Author(s): Yao Yin2, Alejandro Wilcox2, Tabetha S. Boyajian1
Institution(s): 1. Louisiana State University, 2. The Thacher School

325.05 – Rotation Periods and Photometric Amplitudes for Cool Stars with TESS
The original Kepler mission observed 200000 stars in the same field nearly continuously for over four years, generating an unparalleled set of stellar rotation curves and new insights into the correlation between rotation periods and photometric variability on the lower main sequence. The continuation of Kepler in the guise of K2 has allowed us to examine a stellar sample comparable in size to that observed with Kepler, but drawn from new stellar populations. However, K2 observed each field for at most three months, limiting the inferences that can be drawn, particularly for older, slower-rotating stars. The upcoming TESS spacecraft will provide light curves for perhaps two orders of magnitude more stars, but with time windows as short as 27 days. In this work, we resample Kepler light curves using the TESS observing window, and study what can be learned from high-precision light curves of such short lengths, and how to compare those results to what we have learned from Kepler.

Author(s): Hannah Andrews1, Zechariah Domoguzel, Sara Johnson1, Derek L. Buzasi1
Institution(s): 1. Florida Gulf Coast University

325.06 – Further RIOTS4 Characterization of Field OB Stars in the SMC
We present recent results from the Runaways and O-Type Star Spectroscopic Survey of the SMC (RIOTS4), a survey quantifying properties of the field OB stars in the Small Magellanic Cloud (SMC). Based on PSF-fitting photometry and astrometry of OGLE-III I-band images, we quantify the degree of isolation for the target OB stars, classifying them as "tip-of-the-iceberg" stars accompanied by small, sparse, clusters; or as true, isolated field stars. Many of these field stars must be runaways, which we evaluate using GAIA DR2 proper motions. We measure $v\sin i$ using the IACOB code Fourier analysis, finding that the bimodal distribution of projected rotation velocities is less pronounced for O stars than early B stars. We examine rotation in relation to relative isolation and runaway status.

Author(s): M S Oey3, Jesse R. Barnes3, Kevin J. Pasquet3, John Dorigo Jones3, Norberto Castro3, Sergio Simon-Diaz1, Kaitlin M. Kratter2, Maxwell Moe2, Michal Szymanski4
Institution(s): 1. IAC, 2. Univ. of Arizona, 3. Univ. of Michigan, 4. Univ. of Warsaw

325.07 – Study of a few cluster candidates in the Magellanic Bridge
The Magellanic Clouds (LMC & SMC) are gas rich, metal poor, dwarf satellite galaxies to our Milky Way that are interacting with each other. The Magellanic Bridge (MB), joining the larger and smaller Cloud is considered to be a signature of this interaction process. Studies have revealed that the MB, apart from gas also hosts stellar populations and star clusters. The number of clusters, with well-estimated parameters within the MB is still underway. In this work, we study a sample of 9 previously cataloged star clusters in the MB region. We use Washington C, Harris R and Cousins I bands data from literature, taken using the 4-m Blanco telescope to estimate the cluster properties (size, age, reddening). We also identify and separate out genuine cluster candidates from possible clusters/asterism. The increase in number of genuine cluster candidates with well-estimated parameters is important in the context of understanding cluster formation and evolution in such low-metallicity, and tidally disrupted environment. The clusters studied here can also help estimate distances to different parts of the MB, as recent studies indicate that portions of MB near the SMC is a closer to us, than the LMC.

Author(s): Sanyaday Choudhury3, Annapurni Subramaniam Subramaniam2, Young-Jong Sohn1
Institution(s): 1. Department of Astronomy, Yonsei University, 2. Indian Institute of Astrophysics, 3. YONSEI UNIVERSITY OBSERVATORY
325.08 – Eclipsing Binary V1178 Tau: A Reddening Independent Determination of the Age and Distance to NGC 1817

V1178 Tau is a double-lined spectroscopic eclipsing binary in NGC1817, one of the more massive clusters observed in the K2 mission. We have determined the orbital period \(P = 2.20 \, \text{d}\) for the first time, and we model radial velocity measurements from the HARPS and ALFOSC spectrographs, light curves collected by Kepler, and ground based light curves using the Eclipsing Light Curve code (ELC, Orosz & Hauschildt 2000). We present masses and radii for the stars in the binary, allowing for a reddening-independent means of determining the cluster age. V1178 Tau is particularly useful for calculating the age of the cluster because the stars are close to the cluster turnoff, providing a more precise age determination. Furthermore, because one of the stars in the binary is a delta Scti variable, the analysis provides improved insight into their pulsations.

**Author(s):** Anne Hedlund, Eric L. Sandquist, Torben Arendt, Karsten Brogaard, Frank Grundahl, Dennis Stello, Luigi R Bedin, Mattia Libralato, Luca Malavolta, Domenico Nardiello, Joanna Molenda-Zakowicz, Andrew Vanderburg

**Institution(s):** 1. Astronomical Institute of Wroclaw University, 2. San Diego State University, 3. Space Telescope Science Institute, 4. Stellar Astrophysics Centre, Aarhus University, 5. Sydney Institute for Astronomy, University of Sydney, Australia, 6. University of Padova, Italy, 7. University of Texas, Austin

325.09 – On the Observability of Individual Population III Stars and Their Stellar-mass Black Hole Accretion Disks through Cluster Caustic Transits

We summarize panchromatic Extragalactic Background Light data to place upper limits on the integrated near-1R surface brightness (SB) that may come from Population III stars and possible accretion disks around their stellar-mass black holes (BHs) in the epoch of First Light, broadly taken from \(z = 7-17\).

We outline the physical properties of zero-metallicity Population III stars from MESA stellar evolution models through helium depletion and of BH accretion disks at \(z > 7\). We assume that second-generation non-zero-metallicity stars can form at higher multiplicity, so that BH accretion disks may be fed by Roche-lobe overflow from lower-mass companions.

We use these near-infrared SB constraints to calculate the number of caustic transits behind lensing clusters that the James Webb Space Telescope and the next-generation ground-based telescopes may observe for both Population III stars and their BH accretion disks. Typical caustic magnifications can be \(10^4 - 10^5 \times \), with rise times of hours and decline times of \(z \sim 1\) year for cluster transverse velocities of \(v_T < 1000 \, \text{km/s}\).


This work was supported by NASA JWST Interdisciplinary Scientist grants NAG5-12460, NX41AN10G, and 80NSSC18K0200, NASA Theoretical and Computational Astrophysics Networks grant NNX14AB53G, NSF Software Infrastructure for Sustained Innovation grant 1339600, NSF Physics Frontier Center JINA-CEE grant PHY-1430152, Australian Research Council projects AYA2015-64508-P, AYA2012-39475-C02-01, and Ministerio de Economía y Competitividad of Spain Consolider Project CSD2010-00064.

**Author(s):** Rogier A. Windhorst, Stuart Wyithe, Mehmet Alpaslan, F. X. Timmes, Stephen K. Andrews, Duho Kim, Patrick Kelly, Dan A. Coe, Jose M. Diego, Josh M. Diego, Simon P Driver, Mark Dijkstra


400 – Newton Lacy Pierce Prize Talk: Dwarf Galaxies: Laboratories for Nucleosynthesis and Chemical Evolution, Evan Kirby (Caltech)

400.01 – Dwarf Galaxies: Laboratories for Nucleosynthesis and Chemical Evolution

The dwarf galaxies in the Local Group are excellent laboratories for studying the creation of the elements (nucleosynthesis) and the build-up of those elements over time (chemical evolution). The galaxies’ proximity permits spectroscopy of individual stars, from which detailed elemental abundances can be measured. Their small sizes and, in some cases, short star formation lifetimes imprinted chemical histories that are easy to interpret relative to larger, more complex galaxies, like the Milky Way.

I will briefly review some techniques for measuring elemental abundances from medium-resolution spectroscopy of individual stars. I will show how the metallicity distributions of dwarf galaxies reflect their gas content at the time they were forming stars. Then, I will show how the ratio of alpha elements (for example, magnesium) to iron reveals the star formation history. Finally, I will use certain elements to tease out details of nucleosynthetic events. For example, low manganese and cobalt abundances indicate that the typical Type 1a supernova in dwarf galaxies was a low-density white dwarf, and the evolution of barium suggests that neutron star mergers were most likely responsible for the majority of neutron-capture elements in smaller dwarf galaxies.

**Author(s):** Evan N Kirby

**Institution(s):** 1. California Institute of Technology

401 – Other Galaxies

401.02 – Near-Field Cosmology with Resolved Stellar Populations Around Local Volume LMC Stellar-Mass Galaxies

We discuss our ongoing observational program to comprehensively map the entire virial volumes of roughly LMC stellar mass galaxies at distances of \(z = 2-4 \, \text{Mpc}\). The MADCASH (Magellanic Analog Dwarf Companions And Stellar Halos) survey will deliver the first census of the dwarf satellite populations and stellar halo properties within LMC-like environments in the Local Volume. Our results will inform our understanding of the recent DES discoveries of dwarf satellites tentatively affiliated with the LMC/SMC system. This program has already yielded the discovery of the faintest known dwarf galaxy satellite of an LMC stellar-mass host beyond the Local Group, based on deep Subaru/SuprimeCam imaging reaching \(\sim 2\) magnitudes below its TRGB, and at least two additional candidate satellites.

We will summarize the survey results and status to date, highlighting some challenges encountered and lessons learned as we process the data for this program through a prototype LSST
pipeline. Our program will examine whether LMC stellar mass dwarfs have extended stellar halos, allowing us to assess the relative contributions of in-situ stars vs. merger debris to their stellar populations and halo density profiles. We outline the constraints on galaxy formation models that will be provided by our observations of low-mass galaxy halos and their satellites.

Author(s): Jeffrey L. Carlin1, David J. Sand9, Beth Williman1, Jean P. Brodie10, Denija Crnojevic9, Duncan Forbes8, Jonathan R. Hargis7, Annika Peter3, Ragadeepika Pucha6, Aaron J. Romanowsky5, Kristine Spekkens4, Jay Strader8

Institution(s): 1. LSST, 2. Michigan State University, 3. Ohio State University, 4. Royal Military College of Canada, 5. San Jose State University, 6. Steward Observatory/Univ. of Arizona, 7. STScI, 8. Swinburne University, 9. Texas Tech University, 10. UC Santa Cruz

401.03 – The Gaseous Environments of Quasars: Outflows, Feedback & Cold Mode Accretion

The early stages of massive galaxy evolution can involve galaxy-scale outflows driven by a starburst or a central quasar and cold-mode accretion (infall) that adds to the mass buildup in the galaxies. I will describe three related studies that use quasar absorption lines to measure outflows, infall, and the general gaseous environments of quasars across a range of spatial scales. The three studies are: 1) High-resolution spectroscopy with Keck-HIRES and VLTI-UVES to study associated absorption lines (AALs) that have redshifts greater than the emission redshifts indicating infall and/or rich multi-component AAL complexes that might be interstellar clouds in the host galaxies that have been shredded and dispersed by a fast unseen quasar-driven wind. The data provide strong constraints on the gas kinematics, spatial structure, column densities, metallicities, and energetics. 2) A complete inventory of high-velocity CIV 1548,1550 mini-BAL outflows in quasars using high-resolution high signal-to-noise spectra in the public VLTI-UVES and Keck-HIRES archives. This sensitive mini-BAL survey fills an important niche between previous work on narrow absorption lines (NALs) and the much-studied broad absorption lines (BALs) to build a more complete picture of quasar outflows. I will report of the mini-BAL statistics, the diversity of lines detected, and some tests for correlations with the quasar properties. We find, for example, that mini-BALs at v ≥ 4000 km/s in at least 10% of 511 quasars studied, including 1% at v > 0.1 c. Finally, 3) Use the much larger database of NALs measured in 262,449 BOSS quasars by York et al. (in prep.) to study their potential relationships to the quasars and, specifically, their origins in quasar outflows. This involves primarily comparisons of the incidence and properties of NALs at different velocity shifts to other measured properties of the quasars such as BAL outflows, emission line characteristics, radio-loudness, and red colors. We find, for example, that the extreme high-velocity NALs (0.1 – 0.2c) correlate strongly with AALs, indicating that a significant fraction of these NALs is ejected from the quasars.

Author(s): Chen Chen2, Fred Hamann1

Institution(s): 1. University of California, 2. University of Florida

401.04 – Formation of Offset and Dual Active Galactic Nuclei

Galaxy mergers are effective mechanisms for triggering accretion onto supermassive black holes (SMBHs) and thereby powering active galactic nuclei (AGN). In the merger scenario, when the SMBH from only one galaxy is accreting we observe a spatially offset AGN, and when the SMBHs from both galaxies are accreting we observe a dual AGN. Understanding the merger conditions that lead to the formation of offset AGN versus dual AGN is fundamental to informing models of hierarchical SMBH growth and the physics leading to the accretion of matter onto SMBHs. However, while the role of galaxy mergers for AGN triggering has been well-studied, the efficiency with which these events trigger offset AGN versus dual AGN is currently unclear. One reason for this gap in knowledge can be attributed to the observational difficulties in distinguishing between offset and dual AGN since doing so requires high spatial resolution, especially in the small separation regime where merger-driven AGN triggering is most likely to occur. To overcome this hurdle, we have utilized the spatial resolution of the Chandra X-ray Observatory to develop a unique sample of AGN hosted by late-stage galaxy mergers. Moreover, we have recently acquired Hubble Space Telescope imaging for a subset of these systems to examine the role that their merger morphologies play in SMBH growth and the formation of offset and dual AGN. We find that offset AGN are predominantly found in minor mergers, whereas dual AGN are usually hosted by major mergers and galaxies with large morphological asymmetries. Furthermore, in both offset and dual AGN, the rate of SMBH growth increases toward more major mergers and larger morphological asymmetries. These results are in agreement with numerical simulations predicting that merger morphology is a relevant parameter governing SMBH merger-driven growth, and these results are the first to observationally confirm these trends at small pair separations.

Author(s): Scott Barrows2, Julia M. Comerford2, Jenny E. Greene1

Institution(s): 1. Princeton University, 2. University of Colorado Boulder

401.05 – A Comparison of Techniques for Determining Mass Outflow Rates in the Type 2 Quasar Markarian 34

We present spatially resolved measurements of the mass outflow rates and energetics for the Narrow Line Region (NLR) outflows in the type 2 quasar Markarian 34. Using data from the Hubble Space Telescope and Apache point observatory, together with Cloudy photoionization models, we calculate the radial mass distribution of ionized gas and map its kinematics. We compare the results of this technique to global outflow rates that characterize NLR outflows with a single outflow rate and energetic measurement. We find that NLR mass estimates based on emission line luminosities produce more consistent results than techniques employing filling factors.

Author(s): Mitchell Revalski1, D. Michael Crenshaw1, Travis C. Fischer2, Steven B. Kraemer4, Henrique R. Schmitt3, Dzhuliya Dastamirova1, Crystal L Pope1

Institution(s): 1. Georgia State University, 2. NASA Goddard Space Flight Center, 3. Naval Research Laboratory, 4. The Catholic University of America

401.06 – Hypercat - Hypercube of AGN tori

AGN unification and observations hold that a dusty torus obscures the central accretion engine along some lines of sight. SEDs of dust tori have been modeled for a long time, but resolved emission morphologies have not been studied in much detail, because resolved observations are only possible recently (VLT,ALMA) and in the near future (TMT,ELT,GMT). Some observations challenge a simple torus model, because in several objects most of MIR emission appears to emanate from polar regions high above the equatorial plane, i.e. not where the dust supposedly resides.

We introduce our software framework and hypercube of AGN tori (Hypercat) made with CLUMPY (www.clumpy.org), a large set of images (6 model parameters + wavelength) to facilitate studies of emission and dust morphologies. We make use of Hypercat to study the morphological properties of the emission and dust distributions as function of model parameters. We find that a simple clumpy torus can indeed produce 10-micron emission patterns extended in polar directions, with extension ratios compatible with those found in observations. We are able to constrain the range of parameters that produce such morphologies.

Author(s): Robert Nikutta2, Enrique Lopez-Rodriguez3, Kohei ichikawa1, Nancy A. Levenson4, Christopher C. Packham5

Institution(s): 1. National Astronomical Observatory of Japan, 2. NOAO, 3. SOFIA, 4. STScI, 5. UTSA
401.07 – Gas Flows in Dual Active Galactic Nuclei
Dual Active Galactic Nuclei (AGN) are the Rosetta stone to understand the role of galaxy mergers in triggering nuclear activity and regulating black hole (BH) and galaxy growth. But very little is known about the physical processes required to effectively trigger AGN activity and regulate the growth of the two BHs. The work I will present here characterizes for the first time the properties of the stars, gas (molecular, ionized, and highly-ionized) and dust in all the confirmed dual AGN at z < 0.05, using Keck/OSIRIS, VLT/SINFONI, SOFIA/FORCAST, and HST data. I will focus on the interplay between the several complex processes observed in dual AGN, using as an example the prototypical merger system NGC 6240: vigorous star formation, two AGNs, outflowing winds of ionized gas, rippling dust and gas lanes, and tidal tails. In this galaxy, we observe for the first time a dual outflow of different species of gas: an AGN-driven outflow of highly-ionized gas to the northeast and a starburst-driven outflow of ionized hydrogen to the northwest. This shows that stellar feedback and supermassive black hole feedback can work in tandem to regulate the stellar growth of a galaxy after a merger event. These results open a new door to studies of dual AGN and AGN pairs in general, and enable dual AGN to be used, for the first time, for studies of galaxy evolution.

Author(s): Francisco Mueller Sanchez3, Julia M. Comerford3, Richard Davies1, Ezequiel Treister2, George C. Privon2, Becky Nevin3
Institution(s): 1. MPE, 2. Universidad de Chile, 3. University of Colorado Boulder
Contributing team(s): Francisco Muller Sanchez

402 – The Milky Way

402.01 – Astronomy from the Moon: A New Frontier for 21st Century Astrophysics
The International Lunar Observatory Association of Hawai’i USA continues into its second decade with research and development of South Pole instruments for astronomy, observation and communication from the Moon. Since the pioneering first astronomy observations from the Moon by Apollo 16 Commander John Young (an ILOA founding-emeritus director until his recent passing), with China Lunar Ultraviolet Telescope LUT operations and current American and European considerations for far-side radio telescopes, today’s climate is most promising for a diversity of lunar-based astronomy locations, instruments and technologies. ILOA is aiming to advance this frontier through its Galaxy First Light Imaging program, being developed through contracts with Moon Express and Canadensys Aerospace Corp. A wide variety of extreme and unique lunar conditions enable many astronomy activities and installations, on the Moon’s near-side, far-side, north pole, and south pole: The extremely thin lunar exosphere favors observations in millimeter / submillimeter to optical, UV, X-ray, and gamma-ray wavelengths; the highly stable platform that is the Moon provides for long-duration observations; ultra cold, shaded areas for cryogenic infrared instruments; far-side radio–quiet environment for radio telescopes and VLF astronomy; 1/6-Earth gravity for production and utilization of new, very lightweight materials and instruments, including large reflectors, 100-m class liquid mirror telescopes, and possibly 1,000-m class radio telescopes and interferometer antenna arrays vastly larger than Atacama LMA; North and especially South Pole sites, with high peaks and long solar power windows, offer perhaps the widest variety of lunar conditions and opportunities for astronomical innovation on the Moon: a veritable “condominium of observatories”.

Author(s): Steve Durst1
Institution(s): 1. International Lunar Observatory Association (ILOA)

402.02 – R-process Enrichment in Cosmological Zoom Simulation of a MilkyWay Type Halo by Neutron Star Mergers; The Origin of the MP-R and CEMP-R Stars
The history of r-process enrichment in our galaxy is modeled through a novel set of zoom cosmological simulations on a MilkyWay type galaxy. r-process sources are assumed to be neutron star mergers with a distribution of natal kicks and merge time distribution. We model turbulent mixing to estimate the pristine gas fraction in each simulation cell which we use to determine the Pop III star formation with assigned Carbon rich ejecta when going off as SNe. We follow the formation of Carbon-Enhanced Metal-Poor (CEMP) stars and the statistics of different r-process enhanced class of stars. The simulation underpredict the frequency of CEMP/MP stars by a factor of 2-4. Likewise the MP-rI/MP and MP-rII/MP and CEMP-r/CEMP cumulative ratios are all under predicted by 1-2 orders of magnitude. Our results show that NS binaries by themselves fall too short to explain the observed frequency of r-process enhanced stars and other sources of r-process enrichment at high redshifts are needed to fill the gap.

Author(s): Mohammadtaher Safarzadeh1, Evan Scannapieco1
Institution(s): 1. Arizona State University

402.03 – Estimating the Mass of the Milky Way Using the Ensemble of Classical Satellite Galaxies
High precision proper motions are currently available for approximately 20% of the Milky Way’s known satellite galaxies. Often, the 6D phase space information of each satellite is used separately to constrain the mass of the MW. In this talk, I will discuss the Bayesian framework outlined in Patel et al. 2017b to make inferences of the MW’s mass using satellite properties such as specific orbital angular momentum, rather than just position and velocity. By extending this framework from one satellite to a population of satellites, we can now form simultaneous MW mass estimates using the Illustris-Dark cosmological simulation that are unbiased by high speed satellites such as Leo I (Patel et al., submitted). Our resulting MW mass estimates reduce the current factor of two uncertainty in the mass range of the MW and show promising signs for improvement as upcoming ground- and space-based observatories obtain proper motions for additional MW satellite galaxies.

Author(s): Ekta Patel3, Gurtina Beslak3, Sangmo Tony Sohn2, Kaisey Mandel1

402.04 – Sgr A* Emission Parametrizations from GRMHD Simulations
Galactic Center emission near the vicinity of the central black hole, Sagittarius (Sgr) A*, is modeled using parametrizations involving the electron temperature, which is found from general relativistic magnetohydrodynamic (GRMHD) simulations to be highest in the disk-outflow corona. Jet-motivated prescriptions generalizing equipartition of particle and magnetic energies, e.g., by scaling relativistic electron energy density to powers of the magnetic field strength, are also introduced. GRMHD jet (or outflow)/accretion disk/black hole (JAB) simulation postprocessing codes IBOOTHROS and GRMONTY are employed in the calculation of images and spectra. Various parametric models reproduce spectral and morphological features, such as the sub-mm spectral bump in electron temperature models and asymmetric photon rings in equipartition-based models. The
Event Horizon Telescope (EHT) will provide unprecedentedly high-resolution 230+ GHz observations of the “shadow” around Sgr A*’s supermassive black hole, which the synthetic models presented here will reverse-engineer. Both electron temperature and equipartition-based models can be constructed to be compatible with EHT size constraints for the emitting region of Sgr A*. This process sets the groundwork for devising a unified emission parametrization flexible enough to model disk, corona and outflow/jet regions with a small set of parameters including electron heating fraction and plasma beta.

Author(s): Richard Anantua1, Sean Ressler1, Eliot Quataert1
Institution(s): 1. University of California, Berkeley

402.05 – Keck Observations of the Gas Dynamics at the Galactic Center
In the central parsec of the Milky Way Galaxy the environment of the super-massive black hole (SMBH) presents a complicated mixture of stars, gas, and dust. These inner few tens of arcseconds of the GC have been observed at high resolution with Keck for 20 years with the primary goal of monitoring stars orbiting the SMBH. However, the gas features and their dynamics can also be closely examined using this unique baseline of data. In particular, observations with the Keck OSIRIS integral field spectrometer allow us to examine the dynamical properties of the gas and to possibly identify new “G-type” objects, or dusty stellar objects. We present a study of morphology and orbital dynamics of subs-parsec scale gas features in the central region.

Author(s): Randall Campbell3, Anna Ciurlo2, Mark Morris2, Breann N. Sitarski1, Andrea M. Ghez2, Tuan Do2
Institution(s): 1. GMTO, 2. University of California, Los Angeles, 3. W.M. Keck Observatory

403 – LAD: Bridging Laboratory & Astrophysics: Neutron Star Mergers and the r-Process
Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on laboratory astrophysics data needs for modeling and interpreting r-process elements produced in binary neutron star mergers.

403.01 – Signatures of Heavy Element Production in Neutron Star Mergers
Compact object mergers involving at least one neutron star have long been theorized to be sites of astrophysical nucleosynthesis via rapid neutron capture (the r-process). The observation in light and gravitational waves of the first neutron star merger (GW170104) this past summer provided a stunning confirmation of this theory. Electromagnetic emission powered by the radioactive decay of freshly synthesized nuclei from mergers encodes information about the composition burned by the r-process, including whether a particular merger event synthesized the heaviest nuclei along the r-process path, or froze out at lower mass number. However, efforts to model the emission in detail must still contend with many uncertainties. For instance, the uncertain nuclear masses far from the valley of stability influence the final composition burned by the r-process, as will weak interactions operating in the merger’s immediate aftermath. This in turn can affect the color electromagnetic emission. Understanding the details of these transients’ spectra will also require a detailed accounting of the electronic transitions of r-process elements and ions, in order to identify the strong transitions that underlie spectral formation. This talk will provide an overview of our current understanding of radioactive transients from mergers, with an emphasis on the role of experiment in providing critical inputs for models and reducing uncertainty.

Author(s): Jennifer Barnes1
Institution(s): 1. Columbia University

403.02 – Understanding r-process Nucleosynthesis through Nuclear Data
The electromagnetic counterpart of the GW170817 neutron star merger provided the first direct evidence of the astrophysical formation of nuclei via rapid neutron capture (r-process) nucleosynthesis. Full understanding of this event from first principles and its role in galactic chemical evolution requires progress in a number of areas. One key area is nuclear physics. A neutron star merger r-process involves thousands of exotic nuclear species, the majority of which have never been studied in the laboratory. Here we will discuss r-process nuclear data needs and how nuclear physics uncertainties influence our interpretation of observed abundance patterns and kilonova signals. We will explore the promise of experimental campaigns at rare isotope beam facilities to reduce these uncertainties, and describe recent efforts to directly connect nuclear data to astrophysical environments via the ‘reverse-engineering’ of unknown nuclear properties from the r-process abundance pattern.

Author(s): Rebecca Surman1
Institution(s): 1. University of Notre Dame

403.03 – Lanthanide/Actinide Opacities
Gravitational wave observations benefit from accompanying electromagnetic signals in order to accurately determine the sky positions of the sources. The ejecta of neutron star mergers are expected to produce such electromagnetic transients, called macronovae (e.g. the recent and unprecedented observation of GW170817). Characteristics of the ejecta include large velocity gradients and the presence of heavy r-process elements, which pose significant challenges to the accurate calculation of radiative opacities and radiation transport. Opacities include a dense forest of bound-bound features arising from near-neutral lanthanide and actinide elements. Here we present an overview of current theoretical opacity determinations that are used by neutron star merger light curve modelers. We will touch on atomic physics and plasma modeling codes that are used to generate these opacities, as well as the limited body of laboratory experiments that may serve as points of validation for these complex atomic physics calculations.

Author(s): Aimee Hungerford1, Christopher J Fontes1
Institution(s): 1. LANL

404 – Stellar Abundances in Dwarf Galaxies

404.01 – Unraveling the Chemical Evolution of the Magellanic Clouds
How galaxies form and evolve remains one of the cornerstone questions in our understanding of the universe on grand scales. While much progress has been made in understanding the formation and chemical evolution of larger galaxies by studying the Milky Way and other nearby galaxies, our knowledge of the evolution of dwarf galaxies, especially the chemical component, is far more limited because these small galaxies and their constituent stars are quite faint. The SDSS-IV/APOGEE survey will dramatically improve the situation by conducting a large spectroscopic survey of 5,000 giant stars, sampling a large range of radius and position angle, in the nearby Magellanic Clouds (MCs). The main scientific goals of the project are to map out the chemical abundance patterns across the MCs, search for chemical and kinematical substructures, and unravel the chemical evolution of the MCs by comparing the APOGEE abundances to chemical evolution models and sophisticated chemo-
404.02 – A Comparative Analysis of Chemical Abundances in Andromeda's Stellar Halo and Dwarf Galaxies

Stellar halos provide a record of the earliest stages of a galaxy’s formation as well as the mass growth of later epochs. All stages of accretion are represented in the halo: (1) fully phase-mixed stars accreted at early times, (2) stars in distinct tidal streams, and (3) stars in satellite galaxies that will eventually be tidally incorporated into the halo. Chemical abundances encode information about the environment in which a star formed: specifically, the relative abundances of [Fe/H] and [α/Fe] provide an indication of the amount and duration of star formation. While these abundances have been measured for statistically significant samples of halo and dwarf galaxy stars in the Milky Way, they remain largely unknown in Andromeda. We have undertaken a systematic survey to measure [Fe/H] and [α/Fe] in fields throughout the M31 system, including the halo, tidal streams, satellite galaxies, and the disk. I will provide an overview of the survey and its goals and present first results, including the abundance distributions for five M31 dSphs, measurements of [Fe/H] and [α/Fe] of stars in M31's halo, and comparisons to existing measurements of Milky Way dSph and halo stars.

Author(s): Karoline Gilbert3, Evan N Kirby1, Ivanna Escala1, Jennifer Wojno2

404.03 – Higher Signal-to-Noise Measurements of Alpha-element Abundances in the M31 System

The stellar halo and tidal streams of M31 provide an essential counterpart to the same structures around the Milky Way (MW). While measurements of [Fe/H] and [α/Fe] have been made in the MW, little is known about the detailed chemical abundances of the M31 system. To make progress with existing telescopes, we expand upon the technique first presented by Kirby et al., applying spectral synthesis to medium-resolution spectroscopy at lower spectral resolution (R $\approx$ 1800) across an optical range (4100–AA $\lesssim$ 9100–AA) that extends down the blue. We have obtained deep spectra of red giants in the tidal streams, smooth halo, and disk of M31 using the DEIMOS 600ZD grating, resulting in higher signal-to-noise per spectral resolution element (S/N $\approx$ 30 $\lesssim$ AAB$^{-1}$). By applying our technique to red giant stars in MW globular clusters with higher-resolution ($\approx$ 6000) spectra in the blue (4100–6300–AA), we demonstrate that our technique reproduces previous measurements derived from the red side of the optical (6300–9100–AA). For the first time, we present measurements of [Fe/H] and [α/Fe] of sufficient quality and sample size to construct quantitative models of galactic chemical evolution in the M31 system.

Author(s): Ivanna Escala1, Evan N Kirby1
Institution(s): 1. California Institute of Technology

404.04 – Spectroscopic analysis of Cepheid variables with 2D radiation-hydrodynamic simulations

The analysis of chemical enrichment history of dwarf galaxies allows to derive constraints on their formation and evolution. In this context, Cepheids play an important role, as these periodically variable stars provide a means to obtain accurate distances. Besides, chemical composition of Cepheids can provide a strong constraint on the chemical evolution of the system. Standard spectroscopic analysis of Cepheids is based on using one-dimensional (1D) hydrostatic model atmospheres, with convection parametrised using the mixing-length theory. However, this quasi-static approach has not been validated. In my talk, I will discuss the validity of the quasi-static approximation in spectroscopy of short-periodic Cepheids. I will show the results obtained using a 2D time-dependent envelope model of a pulsating star computed with the radiation-hydrodynamics code CO5BOLD. I will then describe the impact of new models on the spectroscopic diagnostic of the effective temperature, surface gravity, microturbulent velocity, and metallicity. One of the interesting findings of my work is that 1D model atmospheres provide unbiased estimates of stellar parameters and abundances of Cepheid variables for certain phases of their pulsations. Convective inhomogeneities, however, also introduce biases. I will then discuss how these results can be used in a wider parameter space of pulsating stars and present an outlook for the future studies.

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405.02 – Waves and Turbulence in the Solar Corona: A Surplus of Sources and Sinks
The Sun’s corona is a hot, dynamic, and highly stochastic plasma environment, and we still do not yet understand how it is heated. Both the loop-filled coronal base and the extended acceleration region of the solar wind appear to be filled with waves and turbulent eddies. Models that invoke the dissipation of these magnetohydrodynamic (MHD) fluctuations have had some success in explaining the heating. In this presentation I will review some new insights about the different ways these waves are thought to be created and destroyed. For example: (1) Intergranular bright points in the photosphere are believed to extend upwards as coronal flux tubes, and their transverse oscillations are driven by the underlying convection. New high-resolution MHD simulations predict the kinetic energy spectra of the resulting coronal waves and serve as predictions for upcoming DKIST observations. (2) Magnetic reconnection in the supergranular network of the low corona can also generate MHD waves, and new Monte Carlo models of the resulting power spectra will be presented. The total integrated power in these waves is typically small in comparison to that of photosphere-driven waves, but they dominate the total spectrum at periods longer than about 30 minutes. (3) Because each magnetic field line in the corona is tied to at least one specific chromospheric footpoint (each with its own base pressure), the corona also plays host to field-aligned “density striations.” These fluctuations vary with the supergranular network on timescales of roughly a day, but they also act as a spatially varying background through which the high-frequency waves propagate. These multiple sources of space/time variability must be taken into account to properly understand off-limb measurements from CoMP and EIS/Hinode, as well as in-situ measurements from Parker Solar Probe.

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405.03 – Possible Detection of Solar Neutrons from the ISS
A low energy steady state solar neutron flux has been long predicted [1]. The Detector for the Analysis of Solar Neutrons (DANSON), designed to detect this flux, was launched on the OA-5 mission to the International Space Station (ISS) on 17 Oct. 2016, deployed aboard ISS, and returned 19 March 2017. This detector is insensitive to high energy solar neutron events associated with solar flares, which have now been routinely detected in the range of 40 to 140 MeV, but the lower energy steady state solar neutron background has not been thoroughly examined. DANSON is based on boron rich detector elements combined with a plastic moderator to thermalize neutrons at energies above 40 MeV, maximizing the $^1$H$^1$O capture of epithermal neutrons. The detector elements include boron carbide ($B_4C$, $H_2$) heterojunction diodes on silicon and lithium tetraborate ($Li_2B_4O_7$) single crystals. Three types of lithium tetraborate detector elements are used: crystals with a natural abundance of $^{10}$B (approx. 20% $^{10}$B, 80% $^{11}$B), crystals enriched in $^{10}$B, and crystals enriched in $^{11}$B. Enrichment in $^{10}$B provides a higher cross section for thermal neutron capture, while enrichment in $^{11}$B results in a negligible cross section for thermal neutron capture while maintaining a proton capture cross section comparable to that of $^{10}$B. The signature of neutron capture in the lithium tetraborate samples is evident in the thermluminescent spectra. In the boron carbide diodes, the signature is measured in the huge decrease in drift carrier lifetimes compared to pre-flight characterization data, corresponding to about $3 \times 10^9$ neutrons/cm$^2$ exposure. Since the estimated total solar exposure time for deployment is $8 \times 10^5$ seconds, this amounts to about 250 to 375 neutrons and protons/cm$^2$sec. The detector package shows increased detection of the neutron side due to cosmic ray generated neutrons. Additionally, detection of events on the nadir side implies detection of cosmic ray generated neutrons.


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405.04 – Tale of Terrestrial Orgins: Hypothesis for Water on the Primordial Mars
It is clear from evidence obtained by Martian orbiters and rovers that the surface of Mars once had flowing water approximately 3.8 Gyr ago. At this time, however, the Sun was approximately 30% less luminous — indicating the Martian surface should not have had a temperature appropriate to explain the existence of liquid water. We investigate a potential solution to this Paint Young Sun Paradox of Mars. We show that Mars could have once been in a circumplanetary orbit about Venus where it would have had a surface temperature conducive to support liquid water given a less luminous Sun. We then model how Mars could have tidally evolved away from Venus until it eventually escaped and migrated to its present orbit. We show that, given the right initial conditions, Mars tends toward an orbit in the vicinity of its present orbit (1.52AU) after escaping Venus and that the rest of the solar system is changed insignificantly from its present configuration. Furthermore, we are working to show that the timescale of the tidal evolution is $\sim 10^8$ to $10^9$ years — long enough to explain the observed geological evidence of water on Mars.

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405.06 – Hubble’s Role in Studies of Venus’ Clouds, Climate and Habitability
Venus’ slow rotation fosters thick cloud formation, via long solar days, low Coriolis forces and strong subsolar convection. Thus, Venus and other slow rotators may maintain an Earth-like climate at 2x the stellar flux as rapid rotators — if the cloud albedo is high, buffering climate change (Yang et al. 2014). However, Venus’ dense $H_2SO_4$ clouds host an absorbing source that drives solar heating, fostering rather than buffering climate change. As such, the response of an atmosphere to the available stellar flux and its impact on habitability will be quite different for a slow rotator planet with Venus-like vs. Earth-like buffering clouds.

2010/2011 HST/STIS observations of Venus have provided data relevant for studying several of the mechanisms that determine Venus’ climate. These observations showed unambiguously that UV photochemistry is not the sole process balancing the growth and loss of the cloud top SO (and SO$_2$). As the parent species of Venus’ $H_2SO_4$ clouds, these results indicated that additional sulfur chemistry must be considered when defining the mechanisms controlling Venus’ $H_2SO_4$ formation process (Jessup et al. 2015). The STIS observations also showed decisively that vertical transport of Venus’ key UV absorbers: $SO_2$, SO and the unnamed absorber are sensitive to the underlying surface elevation (Jessup et al. 2018). This implies that observations made over varying terrain types can be used to parameterize a) the energy and momentum released during surface-atmosphere interactions, which is essential for understanding Venus’ slow body and fast cloud rotation; and b) the sensitivity of the vertical heating rate of the species hosting the greatest impact on Venus’ energy balance and climate to the underlying terrain. Cross-calibration of STIS and Venus Express data also enabled definitive identification of a 6 year decline in the cloud albedo resulting in a nearly 40% increase in the solar heating rate, suggesting dramatic climate change unparalleled in the solar system (Lee et al. 2018). Studies of the links between these phenomena, the super-rotation speed and the solar cycle will be revelatory for inter-stellar habitability studies.
405.07D – A search for evidence of below threshold dielectronic recombination in low temperature plasmas

There are two main types of photoionized gaseous nebulae that exist in the universe, H II regions and Planetary Nebulae (PNe), that mark the endpoints of stellar evolution, and understanding their composition will lead to better understanding of stellar evolution processes, and galactic chemical nucleosynthesis. Determination of heavy elements’ abundances is essential in the analysis of these nebulae. In addition, lines emitted from these heavy elements are typically used for nebular condition deduction. There has been a long-standing problem regarding discrepancy of temperatures and abundances resolved from optical recombination lines and collisionally excited lines. One of the reasons suggested to explain the discrepancy is Dielectric Recombination (DR). DR is thought to necessarily occur through continuum states overlapping with autoionizing states that are above the ionization threshold. Robicheaux et al. (2010) proposed that DR to below threshold states is possible through ‘negative’ energy electrons recombining to below threshold doubly excited states. The spectral lines emitted from this process could provide an efficient mechanism to cool off plasma in addition to having satellite lines blended with collisionally excited lines related to plasma diagnostics. Furthermore, this phenomenon would occur significantly in low temperature plasmas which makes it challenging to prepare an experiment for testing it in a lab. In this research we present a spectroscopic study into this process through observed optical spectra from seven PNe that suffer from abundance discrepancy problem. A code was developed that produces a synthetic spectrum for 2 cases; namely, C IV recombining to C IIII and C IIII to C II. There is faint emission in the optical for these cases. Other possible mechanisms to activate these lines were included in the model and found insignificant. The Auger rates were calculated using the atomic physics code AUTOSTRUCTURE, and the lines were synthesized using a collisional-radiative model.

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405.08 – Saturn Rings Origin: Quantum Trapping of Superconducting Iced Particles and Meissner Effect Lead to the Stable Rings System

Saturn Rings Origin: Quantum Trapping of Superconducting Iced Particles and Meissner Effect Lead to the Stable Rings System
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Abstract
It is demonstrated how superconducting iced particles of the protoplanetary cloud of Saturn are coming to magnetic equator plane and create the stable enough rings disk. There are two steps. First, after appearance of the Saturn magnetic field due to Meissner phenomenon all particles orbits are moving to the magnetic equator plane. Finally they become distributed as rings and gaps like iron particles around magnet on laboratory table. And they are separated from each other by the magnetic field expelled from them. It takes up to few tens of thousands years with ten meters rings disk thickness. Second, due to their quantum trapping all particles become to be trapped within magnetic well at the magnetic equator plane due to Abrikosov vortex for superconductor. It works even when particles have small fraction of superconductor. During the rings evolution some contribution to the disk also could come from the collision-generated debris of the current moon and from the geyseres like it happened due to magnetic coupling of Saturn and Enceladus. The rings are relic of the early days of the magnetic field of Saturn system.

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407 – Plenary Talk: Gaia: Mapping the Milky Way: The Scientific Promise of Gaia DR2, Nicholas Walton (Cambridge)

407.01 – Gaia: Mapping the Milky Way: The Scientific Promise of Gaia DR2

The ESA Gaia mission will release its first major all sky astrometric catalogue (Gaia DR2), of more than 1.3 billion stars in our Galaxy, on 25 April 2018. This presentation will provide an overview of the Gaia mission, focussing on the significant scientific potential of the Gaia DR2 release. This is based on 22 months of input data and allows for a full Gaia stand alone astrometric solution, including parallaxes and proper motions, of over 1.3 billion sources. The astrometric uncertainties in Gaia DR2 will be at the level of tens of microarcsec for sources G<15.

The Gaia DR2 release provides not only high precision full five parameter astrometry, but also a complete photometric catalogue of the sources on an all sky homogeneous photometric system in the Gaia G band and broad bands G_BP and G_RP. The release will include median radial velocities for more than six million stars (brighter that G_RVS = 12) together with a set of astrophysical parameters (including stellar temperatures) for some 150 million stars. Finally the Gaia DR2 release will include a set of additional data products including the light curves of more than half a million variable stars, and the positions of more than thirteen thousand objects in our Solar System.

Together with the Gaia DR2 data products and associated release documentation, a small number of performance verification papers, using Gaia DR2 data only to provide new insights into a number of key areas of Gaia science, will be published in a special edition of A&A. These will provide demonstrations of the scientific potential of the Gaia DR2 catalogue, and also highlight some of the issues and limitations involved in the use of the Gaia DR2 data.

The Gaia mission and Gaia Data Releases are made possible through the dedication and expertise of the community scientists and engineers involved in the design, construction, and operation of Gaia (led by ESA) and the collaboration of some 450 scientists and software engineers responsible for the complex task of analysing the processed data (the DPAC). The role of both will be covered in the presentation.

The presentation will conclude with a brief look ahead to the longer term Gaia data release schedule.

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