230th AAS
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101.01 – Dark Matter in the Universe

“What is the Universe made of?” This question is the longest outstanding problem in all of modern physics, and it is one of the most important research topics in cosmology and particle physics today. The ordinary atoms that make up the known universe, from our bodies and the air we breathe to the planets and stars, constitute only 5% of all matter and energy in the cosmos. The remaining 95% is made up of a recipe of 25% dark matter and 70% dark energy, both nonluminous components whose nature remains a mystery. I’ll begin by discussing the evidence that dark matter is the predominant mass in galaxies, and then turn to the hunt to understand its nature. Leading candidates are fundamental particles including WIMPs (weakly interacting massive particles), axions, and sterile neutrinos. There are three approaches in the experimental searches for WIMPs: at the Large Hadron Collider at CERN in Geneva; in underground laboratory experiments; and with astrophysical searches for dark matter annihilation products. If WIMPs do constitute the dark matter, they would have been the power source for the first stars to form in the Universe; these Dark Stars may be detectable with the upcoming James Webb Space Telescope. At the end of the talk I'll turn to dark energy and its effect on the future of the Universe.

Author(s): Katherine Freese[1]
Institution(s): *1. Univ. of Michigan*

102 – Extrasolar Planets: Detection and Future Prospects

102.01 – M Dwarf Gas Giant Exoplanet Surface Density Distribution: A Log-Normal Fit from 0.07-400 AU

We fit a log-normal function to the orbital surface density distribution of exoplanet populations, over the mass range 1-10 times that of Jupiter, surrounding M dwarfs from 0-400 AU. This fit is consistent with radial velocity, micro-lensing, and direct imaging observations, is well-motivated from theoretical and phenomenological viewpoints, and makes predictions of future surveys. We use a Markov Chain Monte Carlo approach to explore the likelihoods of various parameter values consistent with point estimators of the available data given our assumed functional form. We present probability distributions for each parameter as well as a Maximum Likelihood Estimation solution. We suggest this function makes more physical sense than other widely used functions, and explore the implications of our results on the design of future exoplanet surveys.

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102.02 – Exploring the Effects of Stellar Multiplicity on Exoplanet Occurrence Rates

Determining the frequency of habitable worlds is a key goal of the Kepler mission. During Kepler's four year investigation it detected thousands of transiting exoplanets with sizes varying from smaller than Mercury to larger than Jupiter. Finding planets was just the first step to determining frequency, and for the past few years the mission team has been modeling the reliability and completeness of the Kepler planet sample. One effect that has not typically been built into occurrence rate statistics is that of stellar multiplicity. If a planet orbits the primary star in a binary or triple star system then the transit depth will be somewhat diluted resulting in a modest underestimation in the planet size. However, if a detected planet orbits a fainter star then the error in measured planet radius can be very significant. We have taken a hypothetical star and planet population and passed that through a Kepler detection model. From this we have derived completeness corrections for a realistic case of a Universe with binary stars and compared that with a model Universe where all stars are single. We report on the impact that binaries have on exoplanet population statistics.

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102.03 – Determining Statistically Optimal Metric Thresholds for the Final Kepler Planet Candidate Catalog

The goal of the final Kepler planet candidate catalog is to provide both high completeness and high reliability, to enable accurate planet occurrence rates. This is accomplished through a fully automated vetting procedure that uses thresholds for a variety of metrics to identify planet candidates. Thresholds for many of these metrics can be set using a priori knowledge of how the metrics distinguish between planets and astrophysical false positives. Other metrics, in particular those that distinguish planets from instrumental false alarms, require statistical analysis to find appropriate thresholds. For the latter metrics, we describe the determination of optimal thresholds through the use of a "true positive" population defined via transit injection and a "false positive" population defined via flux inversion and season scrambling. Here "optimal" means simultaneously maximizing completeness and reliability. These optimal thresholds were used as starting points for the final Kepler planet candidate catalog, and were modified in response to corner cases that were not statistically detectable. We examine how the optimal thresholds, and the resulting completeness and reliability, depend on the transit signal strength and transit period. We give special attention to the "Earth analog" region of that parameter space.

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Contributing team(s): The Kepler Team

102.04 – The Final Kepler Planet Candidate Catalog (DR25)

We present Kepler's final planet candidate catalog, which is based on the Q1--Q17 DR25 data release and was created to allow for accurate calculations of planetary occurrence rates. We discuss improvements made to our fully automated candidate vetting procedure, which yields specific categories of false positives and a disposition score value to indicate decision confidence. We present the use of light curve inversion and scrambling, in addition to our continued use of pixel-level transit injection, to produce artificial planet candidates and false positives. Since these simulated data sets were subjected to the same automated vetting procedure as the real data set, we are able to measure both the completeness and reliability of the catalog. The DR25 catalog, source code, and a multitude of completeness and reliability data products are available at the Exoplanet Archive (http://exoplanetarchive.ipac.caltech.edu). The DR25 light curves and pixel-level data are available at MAST (http://archive.stsci.edu/kepler).

Author(s): Jeffrey Coughlin[1], Susan E. Thompson[1]
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Contributing team(s): Kepler Team

102.05 – KELT-11b: A Highly Inflated Sub-Saturn Exoplanet Transiting a V=8 Subgiant Star

We report the discovery of a transiting exoplanet, KELT-11b, orbiting the V=8.0 subgiant HD 93396. The host star is an evolved subgiant star with Teff = 5370K, mass of 1.438 M_{sun}, radius of 2.72 R_{sun}, and logg = 3.727. The planet is a low-mass gas giant in a P = 4.73 day orbit, with a mass of 0.195 M_J and radius 1.37 R_J. KELT-11 is the brightest known transiting exoplanet host in the southern hemisphere by more than a magnitude, and is the 6th brightest transit host to date. The planet is one of the most inflated planets known, with a density of 0.093 g/cm^3, an exceptionally large atmospheric scale height (2763 km), and an associated size of the expected atmospheric transmission signal of 5.6%. These attributes make the KELT-11 system a valuable target for follow-up and atmospheric characterization, and it promises to become one of the benchmark systems for the study of inflated exoplanets.

Author(s): Joshua Pepper[1]
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Contributing team(s): KELT Collaboration

102.06 – KELT-9b: A giant planet with the temperature of a red dwarf star transiting an unevolved A0 star

We report the discovery of KELT-9b, the hottest, most irradiated known hot Jupiter, with a period of ~1.5 days, and radius and mass of ~1.8 Jupiter radii and ~2.7 Jupiter masses. The host is a massive (~2.3 solar masses), hot (effective temperature of ~9,600 K) rapidly-rotating (projected rotation velocity of ~100 km/s) A0 star. Given the implied planetary equilibrium temperature of ~3800 K and scale height of ~1000 km (assuming zero albedo and no heat redistribution), this system provides one of the best targets for detailed characterization of a hot Jupiter atmosphere under extreme irradiation. The planet has been confirmed via high-precision primary transit observations in multiple bands, a lack of companions in deep AO observations, radial velocity detection of the reflex motion of the star due to the companion, detection of the Doppler tomographic signal, and a detection of the secondary eclipse depth in the far-red optical (z) that implies a brightness temperature of ~4600 K, and thus exceptionally poor heat redistribution to the night side. We find that the planet is on a near-polar orbit, likely resulting in orbital precession that will be detectable within a few years. The brightness of the host, the extreme planet temperature, large planet-to-star radius ratio, large planetary atmospheric scale height, and short orbital period, make this an exceptional target for follow-up studies of the planet's atmosphere, which may exhibit unusual photochemistry due to the extreme amount of incident high-energy radiation.

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Contributing team(s): The KELT and KELT-FUN Collaborations

102.07 – NRES: The Network of Robotic Echelle Spectrographs

Las Cumbres Observatory (LCO) is building the Network of Robotic Echelle Spectrographs (NRES), which will consist of four to six identical, optical (390 - 860 nm) high-precision spectrographs, each fiber-fed simultaneously by up to two 1-meter telescopes and a Thorium-Argon calibration source. We plan to install one at up to 6 observatory sites in the Northern and Southern hemispheres, creating a single, globally-distributed, autonomous spectrograph facility using up to ten 1-m telescopes. Simulations suggest we will achieve long-term radial velocity precision of 3 m/s in less than an hour for stars brighter than V = 11 or 12. Following a few months of on-sky evaluation at our BPL test facility, the first spectrograph unit was shipped to CTIO in late 2016 and installed in March 2017. Barring serious complications, we expect regular scheduled science observing to begin in mid-2017. Three additional units are in building or testing phases and slated for deployment in late 2017. Acting in concert, these four spectrographs will provide a new, unique facility for stellar characterization and precise radial velocities. We will briefly overview the LCO telescope network, the NRES spectrograph design, the advantages it provides, and development challenges we encountered along the way. We will further discuss real-world performance from our first unit, initial science results, and the ongoing software development effort needed to automate such a facility for a wide array of science cases.

Author(s): Robert Siverd[3], Timothy M. Brown[3], Todd Henderson[3], John Hygelund[1], Stuart Barnes[7], Mark Bowman[3], Jon De Vera[3], Jason D Eastman[2],Annie Kirby[3], Martin Norbury[6], Cary Smith[3], Brook Taylor[3], Joseph Tufts[5], Julian C. Van Eyken[4]
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102.08 – Future space-based direct imaging platforms: high fidelity simulations and instrument testbed development

The direct detection and characterization of habitable zone (HZ) Earth-like exoplanets is predicated on light gathering power of a large telescope operating with tens of millicarcsecond angular resolution, and at contrast scales on the order of 0.1 ppb. Accessing a statistically significant sample of planets to search for habitable worlds will likely build on the knowledge and insfrastructure gained through JWST, later advancing to assembly in space or formation flying approaches that may eventually be used to achieve even greater photometric sensitivity or resolution. in order to address contrast, a means of starlight suppression is needed that contends with complex aperture diffraction. The Visible Nulling Coronagraph (VNC) is one such approach that destructively interferes starlight to enable detection and characterization of extrasolar objects.

The VNC is being incorporated into an end-to-end telescope-coronagraph system demonstrator called the Segmented Aperture Interferometric Nulling Testbed (SAINT). Development of the VNC has a rich legacy, and successfully demonstrating its capability with SAINT will mark milestones towards meeting the high-contrast direct imaging needs of future large space telescopes. SAINT merges the VNC with an actively-controlled segmented aperture telescope via a fine pointing system and aims to demonstrate 1e-8 contrast nulling of a segmented aperture at an inner working angle of four diffraction radii over a 20 nm visible bandpass. The system comprises four detectors for wavefront sensing, one of which is the high-contrast focal plane. The detectors provide feedback to control the segmented telescope primary mirror, a fast steering mirror, a segmented deformable mirror, and a delay stage. All of these components must work in concert with passive optical elements that are designed, fabricated, and aligned pairwise to achieve the requisite wavefront symmetry needed to push the state of the art in broadband destructive interferometric nulling.

The development of various VNC/SAINT subsystems and components will be presented along with detection performance analyses for several nearby systems assuming a range of space-based architectures spanning mulitple mission lifetimes.

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Contributing team(s): SAINT, VNC, LUVOIR

102.09 – Planets across the HR diagram with the Transiting Exoplanet Survey Satellite Full Frame Images

Discoveries from the Kepler Mission have revealed that planets close to their host stars are common, despite none in our solar system. The Transiting Exoplanet Survey Satellite (TESS) will perform a wide-field survey for planets over ~75% of the sky for the first time. The 30 min cadence TESS Full Frame Images (FFI) will provide observations of more than 10 million stars brighter than magnitude I=16. The FFI targets include stars from all spectral classes, with ages spanning the range ~10 Myr to ~10 Gyr and with metallicities ranging over more than 1 dex.

The FFIs will provide an all-sky magnitude limited sample of short period planetary systems. The precision of TESS will enable planet to be discovered around stars ranging from M-dwarfs, to B-dwarfs. In contrast, the Kepler sample is restricted primarily to main-sequence FGK systems, while the TESS short cadence (2 min) stamps will be centered about cooler stars.

We present the current status of the TESS full frame image (FFI) photometry and candidate detection pipeline. We update the predicted detection rates of sub-Neptunes, super-Neptunes and giant planets using simulated TESS images with realistic noise characteristics. We expect that TESS will find more than 20000 planets with sizes larger than 2 Earth radius around stars with very diverse properties. We discuss how these findings will help resolve many long standing questions, including the planet occurrence rate
as a function of stellar mass, metallicity, and age. Many of these TESS planets will be suitable for ground-based follow up observations that will establish masses, orbital obliquities and eccentricities, which will help improve our understanding of the formation channels of these
close-in planets.

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Contributing team(s): TESS Science Team

103 – Instrumentation, and Things to do with Instrumentation: From the Ground

103.02 – The Eddington Experiment during the 2017 Total Solar Eclipse Will Improve On Prior Work by Near Two Orders of Magnitude

The original Eddington experiment (measuring the gravitational bending of light for stars near a totally eclipsed Sun) in 1919 was one of the most famous and important experiments in all physics, becoming the iconic proof of Einstein's General Relativity (GR). The Eddington experiment has been run successfully for only 7 eclipses, last in 1973, never getting much better than ~10% measurement accuracy. Since then, precision tests of various predictions of GR have been big-time forefront physics, for example the recent discovery of gravitational waves with LIGO. The best measure of the gravitational bending of light comes from radio wavelengths with VLBI, where limits of 0.045% to 0.012% have been reported in the last decade.

A modern version of the Eddington experiment can and should be run for the 21 August 2017 total solar eclipse, when we can improve on the historic results by orders of magnitude. This possibility of greatly improving the Eddington experiment has only just become feasible in the last few years, with the introduction of off-the-shelf CCD cameras with >4k pixels on a side. The near-optimal set of equipment is a 4-inch f/10 refractor with a 4096x4096 CCD all on a GOTO mount. With this, a 7-second image will record 101 unsaturated stars with angular distances from the center of the Sun from 41' to 86', each with centering accuracy of 0.06" to 0.25". A single exposure by itself will measure the gravitational bending of light to 2.3% accuracy. With Gaia positions, and many stars recorded over a large field, plus calibration images from the night sky, all known systematic errors will be much smaller than the final accuracy for any single observer. With many images during totality, _*one*_ observer will measure the GR effect to an accuracy of 0.59%. With many observers, the accuracy will improve by a factor of the square root of the number of observers.

On an independent track, a casual observer can now readily test Einstein's GR by better than anyone has done previously. That is, a 2k CCD with a long telephoto lens can get better than 10% accuracy. With this, laypeople can test Einstein for themselves, and they can see the effects of GR for themselves.

Author(s): Bradley E. Schaefer[1]

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103.03D – Weak Gravitational Lensing in Practice: Instrumentation, Systematics, and Null Tests

Weak gravitational lensing has enormous potential for mapping the growth of large scale structure of our Universe by surveying the way distant galaxy images are slightly distorted by foreground gravitational potentials. However, in the scientific quest for sub-percent precision in cosmological measurements, a multitude of questions have been raised about particular systematic errors which could dominate the accuracy of weak lensing in the era of Stage IV experiments like the LSST. This thesis talk will discuss a few recently discovered instrumental & observational artifacts that have now been extensively measured using a novel benchtop simulation of LSST observing. In particular, systematics such as astrometric error patterns, pixelization biases, and the Brighter-Fatter effect will be discussed, as well as their estimated impact on cosmological parameters. Additionally, examples of these systematics and others will be shown using on-sky data, and the applicability of B-mode systematics null testing will be discussed.

Author(s): Andrew Bradshaw[1]
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103.04 – Optimizing the night time with dome vents and SNR-QSO at CFHT

Night time is a precious and costly commodity and it is important to get everything we can out of every second of every night of observing. In 2012 the Canada-France-Hawaii Telescope started operating 12 new vent doors installed on the dome over the course of the previous two years. The project was highly successful and seeing measurements show that venting the dome greatly enhances image quality at the focal plane. In order to capitalize on the gains brought by the new vents, the observatory started exploring a new mode of observation called SNR-QSO. This mode consist of a new implementation inside our Queued Service Observation (QSO) system. Exposure times are adjusted for each frame depending on the weather conditions in order to reach a specific depth, Signal to Noise Ratio (SNR) at a certain magnitude. The goal of this new mode is to capitalize on the exquisite seeing provided by Maunakea, complemented by the minimized dome turbulence, to use the least amount of time to reach the depth required by the science programs. Specific implementations were successfully tested on two different instruments, our wide field camera MegaCam and our high resolution spectrograph ESPaDOnS. I will present the methods used for each instrument to achieve SNR observing and the gains produced by these new observing modes in order to reach the scientific goals of accepted programs in a shorter amount of time.

Author(s): Daniel Devost[1], Billy Mahoney[1], Claire Moutou[1]
Institution(s): *1. Canada-France-Hawaii Telescope*
Contributing team(s): CFHT QSO team, CFHT software group

103.05 – Laboratory demonstration of Stellar Intensity Interferometry using a software correlator

In this talk I will present measurements of the spatial coherence function of laboratory thermal (black-body) sources using Hanbury-Brown and Twiss interferometry with a digital off-line correlator. Correlations in the intensity fluctuations of a thermal source, such as a star, allow retrieval of the second order coherence function which can be used to perform high resolution imaging and source geometry characterization. We also demonstrate that intensity fluctuations between orthogonal polarization states are uncorrelated but can be used to reduce systematic noise. The work performed here can readily be applied to existing and future Imaging Air-Cherenkov telescopes to measure spatial properties of stellar sources. Some possible candidates for astronomy applications include close binary star systems, fast rotators, Cepheid variables, and potentially even exoplanet characterization.

Author(s): Nolan Matthews[1], David Kieda[1]
Institution(s): *1. University of Utah*

103.06 – Stellar Intensity Interferometric Capabilities of IACT Arrays

High resolution astronomical optical imaging of nearby main sequence stars and binary systems can provide critical information on stellar phenomena such as rotational deformation, accretion effects, and the universality of starspot (sunspot) cycles. This talk will describe the development of a milli-arc-second resolution Stellar Intensity Interferometry (SII) imaging technique using Hanbury Brown and Twiss (HBT) interferometry. We describe the development of SII instrumentation using high speed (>250 Mhz) continuous streaming digitizers, multi-crate timing using fiber optic (White Rabbit) synchronization, and an offline, software-based correlator. This instrumentation allows construction of an SII optical imaging observatory with a widely spaced array of Imaging Air Cherenkov Telescopes (IACTs). The talk describes the potential SII imaging resolution of the VERITAS IACT observatory array (Amado, Arizona) and the future CTA IACT Observatory (Canary Islands, Spain and Paranal, Chile).

Author(s): David Kieda[1], Nolan Matthews[1]
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Contributing team(s): CTA Collaboration

103.07 – Examining Moderate Volatile Loss through Lunar History

While the Moon and bulk silicate earth (BSE) share many compositional similarities, a notable difference is the apparent depletion of moderate volatiles in lunar samples. Depletion of elements such as sodium and potassium relative to BSE composition has been observed in Apollo samples. The source of these depletions is poorly understood but may be a result of preferential accretion of volatile-rich melt in the inner disk to the Earth during Moon formation.

However, recent Kepler data has indicated that stellar analogues to our Sun experience enhanced flare activity early in their evolution. This implies that the Sun may have had a higher frequency and energy of flares and associated Coronal Mass Ejections (CME) in its distant past. We examine the potential impacts of this increased activity on lunar exosphere generation and specifically on potential loss of moderate volatiles including sodium and potassium.

We use a surface bounded exosphere model that incorporates multiple processes including photon stimulated desorption, kinetic sputtering and impact vaporization in order to study potential moderate volatile loss under a variety of different conditions. This model is informed by appropriate solar wind and CME properties, which includes CMEs of different energies. We also incorporate regolith overturn to determine ranges of potential bulk depletion of moderate volatiles from the lunar regolith.

Our work is aimed at determining the potential impact of solar activity on the depletion of moderate volatiles in the lunar regolith. Such a contribution is important to ascertain in order to isolate the depletion of volatiles due to disk processes and may thus help constrain details of the Moon's formation. Finally, we also examine the potential of lunar abundances of moderate volatiles as an observational tracer of past solar activity.

Author(s): Prabal Saxena[1], Rosemary M. Killen[1], Vladimir Airapetian[1], Noah Petro[1], Avi Mandell[1]
Institution(s): *1. NASA GSFC*

103.08 – First Results from VLBA Astrometry of Juno

We have used the Very Long Baseline Array (VLBA) to determine precise positions of the Juno spacecraft during its approach to Jupiter and during its third perijove pass after orbit insertion. VLBA observations will continue during several perijove passes until the end of Juno's mission. The orbit of Juno about Jupiter is most accurately determined by Doppler tracking near perijove, allowing our Juno position measurements to be transferred to the Jupiter system barycenter. We use angularly nearby extragalactic radio sources with known positions in the International Celestial Reference Frame as phase reference sources during VLBA observations to obtain accurate positions for Jupiter in an inertial reference frame. The planned series of Jupiter position measurements will be used to improve the accuracy of Jupiter's orbit in the JPL planetary ephemeris. The improvement is most dramatic in orbit inclination and ascending node; spacecraft ranging provides the best constraints on semi-major axis and eccentricity. Similar VLBA observations of the Cassini spacecraft orbiting Saturn during the past decade have improved our knowledge of Saturn's orbit by nearly an order of magnitude, and we expect a similar improvement for Jupiter. This research is partially funded by a grant from NASA's Planetary Astronomy program to the Space Science Institute, Boulder, CO. Part of this work is being carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. The Long Baseline Observatory and the National Radio Astronomy Observatory are facilities of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

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Institution(s): *1. JPL, 2. Long Baseline Observatory, 3. NRAO, 4. Space Science Institute*

104 – Topics in Astrostatistics

The field of AstroStatistics is at this intersection of observational Astronomy, Statistics, and data science. A functional literacy in AstroStatistics is becoming a necessity for astronomers who are confronted with high-quality datasets from modern instruments. New astronomical datasets pose unprecedented data analytic challenges with complex data that aim to improve our understanding of the Universe, provided that they are carefully analyzed and uncertainties are accounted for correctly. This requires descriptive science-driven statistical models and methods that relate our best underlying physical processes to observables. For a number of AAS meetings, we have been organizing lectures on basic methods, and these have proven to be highly popular. We plan to continue this series with talks covering topics such as hypotheses testing and Machine Learning applied to Big Data problems.

104.01 – The Bayesian Statistics behind Calibration Concordance

Calibration data for instruments used for astrophysical measurements are usually obtained by observing different astronomical objects with well-understood characteristics simultaneously with different detectors. How to adjust the effective areas of the detectors to achieve concordance among the sources observed by the several detectors is the problem of interest. The calibration concordance problem can be addressed by introducing a log-Normal approach for a multiplicative mean model given by physics. In this context, I will introduce concepts of Bayesian hierarchical model, log-Normal regression model and shrinkage estimators, and give intuitive interpretations of the model and the results. Model fitting is achieved by running the Markov chain Monte Carlo (MCMC) algorithm, the basics of which will also be covered.

Author(s): Yang Chen[1]
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Contributing team(s): Vinay Kashyap, David van Dyk, Xufei Wang, Xiao-Li Meng, Herman Marshall

104.02 – The Potential of Deep Learning with Astronomical Data

Modern astronomical surveys yield massive catalogs of noisy high-dimensional objects, e.g., images, spectra, and light curves. Valuable information stored in individual objects can be lost when ad hoc approaches of feature extraction are used in an effort to build data sets amenable to established data analysis tools. Deep learning procedures provide a promising avenue to enabling the use of data in their raw form and hence allowing both for estimates of greater accuracy and for novel discoveries with greater confidence. This talk will give an overview of deep learning and its potential in astronomical applications.

Author(s): Chad Schafer[1]
Institution(s): *1. Carnegie Mellon University*

104.03 – Recurrent Neural Network Applications for Astronomical Time Series

The benefits of good predictive models in astronomy lie in early event prediction systems and effective resource allocation. Current time series methods applicable to regular time series have not evolved to generalize for irregular time series. In this talk, I will describe two Recurrent Neural Network methods, Long Short-Term Memory (LSTM) and Echo State Networks (ESNs) for predicting irregular time series. Feature engineering along with a non-linear modeling proved to be an effective predictor. For noisy time series, the prediction is improved by training the network on error realizations using the error estimates from astronomical light curves. In addition to this, we propose a new neural network architecture to remove correlation from the residuals in order to improve prediction and compensate for the noisy data. Finally, I show how to set hyperparameters for a stable and performant solution correctly. In this work, we circumvent this obstacle by optimizing ESN hyperparameters using Bayesian optimization with Gaussian Process priors. This automates the tuning procedure, enabling users to employ the power of RNN without needing an in-depth understanding of the tuning procedure.

Author(s): Pavlos Protopapas[1]
Institution(s): *1. Harvard*

105 – Inner Solar Systems: Planet Compositions as Tracers of Formation Location

105.01 – C/O atmosphere measurements

The atmospheric carbon-to-oxygen ratio is believed to be a key to formation scenario of exoplanets. Due to different condensation temperatures for water, carbon oxide, and carbon dioxide, their "icelines" are situated at different parts of the protoplanetary disk resulting in different C/O ratio values through the disk. Therefore, by measuring a C/O ratio in the atmosphere of a giant exoplanet, we should be able to understand the planet's formation.

I will give a brief overview of recent theoretical studies that predict how various mechanisms during planet formation (e.g. migration, pebble drift) may affect the feasability of using a C/O ratio to understand formation of exoplanets.

In the second part of my talk, I will discuss various methods of measuring abundances in atmospheres. I will also talk about how to take into account systematic effects in observations and atmospheric models and if there is a possibility to determine and apply "C/O ratio indices".

Author(s): Taisiya Kopytova[1]
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105.02 – The Role of Ice Compositions and Disk Dynamics for Snowlines and C/N/O Ratios in Active Disks

The elemental compositions of planets define their chemistry, and could potentially be used as beacons for their formation location if the elemental gas and grain ratios of planet birth environments, i.e. protoplanetary disks, are well understood. In disks, the ratios of volatile elements, such as C/O and N/O, are regulated by the abundance of the main C, N, O carriers, their ice binding environment, and the presence of snowlines of major volatiles at different distances from the central star. I explore the effects of disk dynamical processes and ice compositions on the snowline locations of the main C, O and N carriers, and the C/N/O ratios in gas and dust throughout the disk. The gas-phase N/O ratio enhancement in the outer disk (exterior to the H_2O snowline) exceeds the C/O ratio enhancement for all reasonable volatile compositions. Ice compositions and disk dynamics individually change the snowline locations of CO and N_2 by a factor of 2-3, and when considered together the range of possible CO and N_2 snowline locations is ~10 - ~70 AU in a standard disk model. Observations that anchor snowline locations at different stages of planet formation are therefore key to develop C/N/O ratios as a probe of planet formation zones.

Author(s): Ana-Maria Piso[1]
Institution(s): *1. UCLA*

105.03 – Forming Super-Puffs Beyond 1 AU

Super-puffs are an uncommon class of short-period planets seemingly too voluminous for their small masses (4–10 Rearth, 2–6 Mearth). Super-puffs most easily acquire their thick atmospheres as dust-free, rapidly cooling worlds outside ~1AU where nebular gas is colder, less dense, and therefore less opaque.

These puffy planets probably migrated in to their current orbits; they are expected to form the outer links of mean-motion resonant chains, and to exhibit atmospheric characteristics consistent with formation at large distances. I will also discuss, in general, how densities of planets can be used to infer their formation locations.

Author(s): Eve J Lee[1], Eugene Chiang[1]
Institution(s): *1. UC Berkeley*

106 – Annie Jump Cannon Award: Origins of Inner Solar Systems, Rebekah Dawson (Penn State University)

Over the past couple decades, thousands of exoplanets have been discovered on orbits interior to 1 AU, from hot Jupiters orbiting close to their host stars to systems of dynamically-packed super-Earths. Despite exquisite observations of individual worlds, statistical analyses of the growing collection of objects, and extensive simulations of their formation and evolution, the origins of inner Solar Systems remain debated. Inner Solar Systems brings together experts from different perspectives to address outstanding questions about the origins of inner solar systems. We focus on questions where there is tension between observations and theory or different models or interpretations. Each panel-based session addresses a single outstanding question and is led by a panel chair who introduces the topic, moderates the discussion among panelists, and engages the audience in identifying the next steps to resolving the question.

106.01 – Origins of Inner Solar Systems

Over the past couple decades, thousands of extra-solar planetshave been discovered orbiting other stars. The exoplanets discovered to date exhibit a wide variety of orbital and compositional properties; most are dramatically different from the planets in our own Solar System. Our classical theories for the origins of planetary systems were crafted to account for the Solar System and fail to account for the diversity of planets now known. We are working to establish a new blueprint for the origin of planetary systems and identify the key parameters of planet formation and evolution that establish the distribution of planetary properties observed today. The new blueprint must account for the properties of planets in inner solar systems, regions of planetary systems closer to their star than Earth's separation from the Sun and home to most exoplanets detected to data. I present work combining simulations and theory with data analysis and statistics of observed planets to test theories of the origins of inner solars, including hot Jupiters, warm Jupiters, and tightly-packed systems of super-Earths. Ultimately a comprehensive blueprint for planetary systems will allow us to better situate discovered planets in the context of their system's formation and evolution, important factors in whether the planets may harbor life.

Author(s): Rebekah Ilene Dawson[1]
Institution(s): *1. The Pennsylvania State University*

108 – Astronomy Education: Research, Practice, and Outreach Across the Human Continuum

108.01 – Understanding Students' Ideas about the Geometry of the Universe

As astronomers further develop an understanding of the geometry of the Universe, it is essential to study students' ideas so that instructors can communicate the field's current status more effectively to their students. In this study, we examine undergraduate students' pre- instruction ideas in general education astronomy courses (ASTRO 101) at three institutions through pre-course surveys given during the first week of instruction [N ~ 265]. We also examine students' post-instruction ideas at a single institution through exam questions [N ~ 75] and interviews. Responses are analyzed through an iterative process of identifying self-emergent themes. We examine not only what students think the curvature of the universe is, but also "how we know." We find that many students think the Universe is "round" or that we cannot measure its curvature. Additionally, popular visualizations may enforce incorrect ideas.

Author(s): Kimberly A. Coble[1], Mallory Conlon[3], Janelle M. Bailey[2]
Institution(s): *1. San Francisco State Univ., 2. Temple University, 3. University of Illinois*

108.02 – Star Maps, Planispheres, and Celestial Calendars : Engaging Students, Educators, and Communities with Multicultural STEM/STEAM Visual Resources

Aim:
Designed by A. Lee, the *Native Skywatchers* initiative seeks to remember and revitalize indigenous star and earth knowledge, promoting the native voice as the lead voice. The overarching goal of *Native Skywatchers* is to communicate the knowledge that indigenous people practiced a sustainable way of living and sustainable engineering through a living and participatory relationship with the above and below, sky and earth. We aim to improve current inequities in education for native young people, to inspire increased cultural pride, and promote community wellness. We hope to inspire all participants towards a rekindling of the excitement and curiosity that causes us to look up at the sky in wonder generation after generation.
Results:
Presented here are several *Native Skywatchers* initiatives under the broad categories of: 1.) star maps, 2.) planispheres, and 3.) celestial calendars. In 2012 two indigenous star maps were created: the *Ojibwe Giizhig Anung Masinaaigan*- Ojibwe Sky Star Map (A. Lee, W. Wilson, C. Gawboy),

and the D(L)akota star map, *Makoce Wicanhpi Wowapi* (A. Lee, J. Rock). More recently, a collaboration with W. Buck, science educator, at the Manitoba First Nations Resource Centre (MFNRC), in Winnipeg, Manitoba produced a third indigenous star map: *Ininew Achakos Masinikan*-Cree Star Map Book. Having star maps that are rooted in astronomical knowledge and cultural wisdoms has allowed communities multiple and ongoing opportunities for inclusive culture-based STEM learning. Next, planispheres were created based on the indigenous star maps. A learning and teaching hands-on tool, the planispheres, help partakers understand the patterns of motion in the night sky in addition to simply identifying the constellations. Most recently, calendar-paintings of the yearly motion of the Sun, the phases of the Moon, and the Venus-year have all been added to the growing list of *Native Skywatchers* resources. Working collaboratively with regional schools, educators, museums, liaisons, and communities this work offers a solid example of how community based participatory programs can be the spark for effective culture-based STEM learning.

Author(s): Annette S. Lee[3], William Wilson[2], Jeffrey Tibbetts[2], Carl Gawboy[1]
Institution(s): *1. College of Saint Scholastica, 2. Fond du Lac Tribal and Community College, 3. St. Cloud State University*

108.03 – Bridging Scientific Expertise to Underserved Communities: Initiating and Sustaining Local STEM Outreach

This presentation will feature effective outreach strategies used to recruit, engage, and sustain student involvement from underserved communities in out-of-school science outreach programs. For example, one strategy is to partner with subject matter experts to provide your audience with a deeper understanding of and a unique perspective on current science. Join us to learn more about how you can initiate and sustain a STEM based program in your local community.

Author(s): Tania Anderson[1], Jessica Kenney[1], John Maple[1]
Institution(s): *1. Space Telescope Science Institute*

108.04 – Books and Other Resources for Education about the August 21, 2017, Solar Eclipse

As part of our work to reach and educate the 300+ million Americans of all ages about observing the August 21 solar eclipse, especially by being outdoors in the path of totality but also for those who will see only partial phases, we have compiled annotated lists of books, pamphlets, travel guides, websites, and other information useful for teachers, students, and the general public and made them available on the web, at conferences, and through webinars. Our list includes new eclipse books by David Barron, Anthony Aveni, Frank Close, Tyler Nordgren, John Dvorak, Michael Bakich, and others. We list websites accessible to the general public including those of the International Astronomical Union Working Group on Eclipses (http://eclipses.info, which has links to all the sites listed below); the AAS Eclipse 2017 Task Force (http://eclipse2017.aas.org); NASA Heliophysics (http://eclipse.nasa.gov); Fred Espenak (the updated successor to his authoritative "NASA website": http://EclipseWise.com); Michael Zeiler (http://GreatAmericanEclipse.com); Xavier Jubier (http://xjubier.free.fr/en/site_pages/solar_eclipses/) ; Jay Anderson (meteorology: http://eclipsophile.com); NASA's Eyes (http://eyes.nasa.gov/eyes-on-eclipse.html and its related app); the Astronomical Society of the Pacific (http://www.astrosociety.org/eclipse); Dan McGlaun (http://eclipse2017.org/); Bill Kramer (http://eclipse-chasers.com). Specialized guides include Dennis Schatz and Andrew Fraknoi's *Solar Science* for teachers (from the National Science Teachers Association: http://www.nsta.org/publications/press/extras/files/solarscience/SolarScienceInsert.pdf), and a printing with expanded eclipse coverage of Jay Pasachoff's, *Peterson Field Guide to the Stars and Planets* (14th printing of the fourth edition, 2016: http://solarcorona.com).
A version of our joint list is to be published in the July issue of the *American Journal of Physics* as a Resource Letter on Eclipses, adding to JMP's 2010, "Resource Letter SP-1 on Solar Physics," *AJP*, **78**, September, 890-901.

Author(s): Jay M. Pasachoff[3], Andrew Fraknoi[2], Michael Kentrianakis[1]
Institution(s): *1. AAS Solar Eclipse Task Force, 2. Foothill College, 3. Williams College*

108.06 – *Astronomy4Kids*: Extending STEM learning to the youngest student through an online educational outreach program

Astronomy4Kids is an online video series aimed at filling the void of effective and engaging education tools within early childhood learning. Much discussion and research has been conducted on the significance of early learning, with general trends showing significant benefits to early introductions to language, mathematics, and general science concepts. Ultimately, when ideas are introduced to a child at a young age, that child is better prepared for when the concept is re-introduced in its entirety later. National agencies—such as the AAS and NSF—have implemented Science, Technology, Engineering, and Math (STEM) initiatives to expand learning in these areas. However, despite these many resources, the education outreach available to the youngest learners (under the age of 8 or those from pre-school to about 2nd-grade) is seriously lacking. *Astronomy4Kids* was created to bridge this gap and provide succinct, creative-learning videos following the principles of Fred Rogers, the founder of preschool education video. We present ways to incorporate the freely accessible YouTube videos within various classroom ages and discuss how to use simple activities to promote physics, astronomy, and math learning. Current development, video statistics, and future work will be discussed. The freely accessible videos can be found at www.astronomy4kids.net.

Author(s): Richard L Pearson[1], Sarah R Pearson[1]
Institution(s): *1. Astronomy4Kids*

108.07 – The Hubble Frontier Fields: Engaging Multiple Audiences in Exploring the Cosmic Frontier

The Hubble Frontier Fields is a multi-cycle program of six deep-field observations of strong-lensing galaxy clusters taken in parallel with six deep "blank fields." The three-year long collaborative program began in late 2013 and is led by observations from NASA's Great Observatories. The observations, now complete, allow astronomers to look deeper into the universe than ever before, and potentially uncover galaxies that are as much as 100 times fainter than what the telescopes can typically observe. The Frontier Fields science program is ideal for informing audiences about scientific advances and topics in STEM. The study of galaxy properties, statistics, optics, and Einstein's theory of general relativity naturally leverages off of the science returns of the Frontier Fields program. As a result, the Space Telescope Science Institute's Office of Public Outreach (OPO) has engaged multiple audiences over the past three years to follow the progress of the Frontier Fields.

For over two decades, the STScI outreach program has sought to bring the wonders of the universe to the public and engage audiences in the adventure of scientific discovery. In addition, we are leveraging the reach of the new NASA's Universe of Learning education program to bring the science of the Frontier Fields to informal education audiences. The main underpinnings of the STScI outreach program and the Universe of Learning education program are scientist-educator development teams, partnerships, and an embedded program evaluation component. OPO is leveraging the infrastructure of these education and outreach programs to bring the Frontier Fields science program to the education community and the public in a cost-effective way.

This talk will feature highlights over the past three years of the program. We will highlight OPO's strategies and infrastructure that allows for the quick delivery of groundbreaking science to the education community and public.

Author(s): Brandon L. Lawton[1], Denise A. Smith[1], Frank Summers[1], Holly Ryer[1], Carolyn Slivinski[1], Jennifer M. Lotz[1]
Institution(s): *1. STScI*

108.08 – Inspiring the Next Generation: Astronomy Catalyzes K12 STEM Education

K-12 educators need effective and relevant astronomy professional development. NASA's Mission Science provides innovative and accessible opportunities for K-12 teachers. Science questions involve scale and distance, including Moon/Earth scale, solar system scale, and distance of objects in the universe. Teachers can gain an understanding of basic telescopes, the history of telescopes, ground and satellite based telescopes, and models of JWST Telescope. An in-depth explanation of JWST and Spitzer telescopes gave participants background knowledge for infrared astronomy observations. During teacher training, we taught the electromagnetic spectrum through interactive stations. The stations included an overview via lecture and power point, the use of ultraviolet beads to determine ultraviolet exposure, the study of lenticulars and diagramming of infrared data, looking at visible light through diffraction glasses and diagramming the data, protocols for using astronomy based research in the classroom, and infrared thermometers to compare environmental conditions around the observatory. An overview of LIDAR physics was followed up by a simulated LIDAR mapping of the topography of Mars.
We will outline specific steps for K-12 infrared astronomy professional development, provide data demonstrating the impact of the above professional development on educator understanding and classroom use, and detail future plans for additional K-12 professional development.
Funding was provided by Washington STEM, NASA, and the Washington Space Grant Consortium.

Author(s): Kareen Borders[3], Michelle Thaller[1], Robert Winglee[1], Kyla Borders[2]
Institution(s): *1. NASA, 2. University of Washington, 3. Washington STEM*

108.09 – Emerging Technologies and Outreach with JWST

The James Webb Space Telescope (JWST), NASA's next great observatory launching in October 2018, required a dozen new technologies to develop. How will we maintain the prestige and cultural impact of Hubble as the torch passes to Webb? Emerging technologies such as augmented and virtual reality bring the viewer into the data and the concept in previously unimaginable immersive detail. Adoption of mobile devices has expanded access to information for wide swaths of the public. Software like Worldwide Telescope to hardware like the Occulus Rift are providing new avenues for learning. If we develop materials properly tailored to this medium, we can reach more diverse audiences than ever before. STScI is pioneering some tools related to JWST for showcasing at AAS, and in local events, which I highlight here.

Author(s): Joel D. Green[1], Denise A. Smith[1], Bonnie K. Meinke[1], Brandon L. Lawton[1], Jessica Kenney[1], Hussein Jirdeh[1]
Institution(s): *1. Space Telescope Science Institute*

109 – Bridging Laboratory & Astrophysics: Atomic Physics

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the interplay between astrophysics with theoretical and experimental studies into the underlying atomic processes that drive our Universe.

109.01 – LAD Prize Talk: Lab Astro and the Origins of the Chemical Elements

Only a few of the lightest or primordial nuclei were made just after the Big Bang. Other light nuclei up to the Fe-group are made by fusion in stars. Heavier nuclei are made primarily via *r(apid)*-process and *s(low)*-process *n(eutron)*-capture events. Although the *s*-process *n*-capture is fairly well understood, the *r*-process *n*-capture events remain poorly understood. The relative role of Core Collapse SNe and *n*-star mergers will likely be understood in the next few decades. I will discuss recent studies of old Metal-Poor stars that are revealing some new details of nucleosynthesis. This progress is due to the availability of high resolution spectra from large ground based telescopes, access to the UV via HST, and better laboratory data. Our laboratory astrophysics program has focused primarily on the measurement of transition probabilities by combining radiative lifetimes with emission branching fractions. The use of Time Resolved Laser Induced Fluorescence (TRLIF) to measure radiative lifetimes in metallic atoms and ions provides an absolute scale for transition probabilities accurate to a few percent [e.g. 1]. The development and application of TRLIF to neutral and ionized atoms of nearly all elements is due to a simple, versatile, and reliable atom/ion beam source based on a hollow cathode discharge [2, 3]. Fourier transform spectrometers (FTSs) are essential in the measurement of emission branching fractions for atoms and ions with dense spectra such as the rare earths [e.g. 4, 5]. A 3 m focal length echelle spectrometer is important to the measurement of weak branches which might otherwise be obscured by multiplex noise in FTS data [6, 7]. References: [1] E. A. Den Hartog et al., ApJS 194: 35 (2011). [2] D. W. Duquette et al., Phys. Rev. A24, 2847 (1981). [3] S. Salih & J. E. Lawler, Phys. Rev. A29, 3753, (1983). [4] J. W. Brault, J. Opt. Soc. Am. 66, 1081 (1976). [5] J. E. Lawler et al., ApJS 182, 51 (2009). [6] M. P. Wood & J. E. Lawler, Appl. Opt. 51, 8407 (2012). [7] C. Sneden et al., ApJ 817:53 (2016).

Author(s): James E. Lawler[1]
Institution(s): *1. University of Wisconsin - Madison*

109.02 – Estimating uncertainties on atomic data and their effects on line ratio diagnostics

Results are presented of recent work exploring methods that can be used to estimate uncertainties on atomic rate coefficients, for use in astrophysical diagnostics and modeling. These methods include more approximate approaches to determine an initial range for the uncertainties and their effects on spectral line intensities, and advanced methods aimed at determining a more precise uncertainty on a particular set of theoretical calculations. We use the R-matrix method to calculate electron-impact excitation data, as an illustration of the uncertainty estimates with associated correlation information. A number of line ratio examples are presented to highlight the effects that correlated uncertainties would introduce.

Author(s): Stuart Loch[1], Alejandra Mendez[2], Hans Werner Van Wyck[1], Connor Ballance[3], Adam Foster[4]
Institution(s): *1. Auburn University, 2. Instituto de Astronomía y Física del Espacio, 3. Queen's University of Belfast, 4. Smithsonian Astrophysical Observatory*

109.03D – Charge Exchange: Velocity Dependent X-ray Emission Modeling

Atomic collisions play a fundamental role in astrophysics, plasma physics, and fusion physics. Here, we focus on charge exchange (CX) between hot ions and neutral atoms and molecules. Even though charge exchange calculations can provide vital information, including neutral and ion density distributions, ion temperatures, elemental abundances, and ion charge state distributions in the environments considered, both theoretical calculations and laboratory studies of these processes lack the necessary reliability and/or coverage. In order to better understand the spectra we observe in astrophysical environments in which both hot plasma and neutral gas are present, including comets, the heliosphere, supernova remnants, galaxy clusters, star forming galaxies, the outflows of starburst galaxies, and cooling flows of hot gas in the intracluster medium, a thorough CX X-ray model is needed. Included in this model should be a complete set of X-ray line ratios for relevant ion and neutral interactions for a range of energies.

In this work, theoretical charge exchange emission spectra are produced using cross sections calculated with widely applied approaches including the quantum mechanical molecular orbital close coupling (QMOCC), atomic orbital close coupling (AOCC), classical trajectory Monte Carlo (CTMC), and the multichannel Landau-Zener (MCLZ) methods. When possible, theoretical data are benchmarked to experiments. Using a comprehensive, but still far from complete, CX database, new models are performed for a variety of X-ray emitting environments. In an attempt to describe the excess emission in X-rays of the starburst galaxy M82, Ne X CX line ratios are compared to line ratios observed in the region. A more complete XSPEC X-ray emission model is produced for H-like and He-like C-Al ions colliding with H and He for a range of energies; 200 to 5000 eV/u. This model is applied to the northeast rim of the Cygnus Loop supernova remnant in an attempt to determine the contribution of CX within that region.

This work was partially supported by NASA grants NNX09AC46G and NNG09WF24I and accomplished with the help of many collaborators including Phillip C. Stancil, David Lyons, Patrick Mullen, and Robin L. Shelton.

Author(s): Renata Cumbee[1]
Institution(s): *1. NASA Goddard Space Flight Center*

110 – Preparing for JWST Observations: Insights from First Light and Assembly of Galaxies GTO Programs I

Opportunities to propose Early Release Science (ERS) observations for the James Webb Space Telescope (JWST) are now available. JWST General Observer (GO) program opportunities will be available in just a few months (November 2017). How can you prepare a successful JWST observing program? Here the Guaranteed-Time Observers (GTO) will describe how they turned their science into JWST observing programs, including JWST proposal planning tool use case examples. This session will focus primarily on First Light and Assembly of Galaxies JWST GTO Programs.

110.01 – Putting the James Webb Space Telescope to Work

The time for community members to submit their initial observing proposals for using the James Webb Space Telescope is rapidly approaching. The Early Release Science proposals are due in two months (18-August) and cycle 1 General Observer proposals will be due 2-March 2018. This meeting-in-a-meeting is designed to show how the guaranteed time observing teams have navigated this process of turning science questions into valid Webb proposal files. We hope the lessons they have learned can be passed to you, making your proposals better and the process more efficient. Before presentations from the science team members I will give a status of the mission and look forward to the remaining activities prior to the activation of the first cycle of your observations.

Author(s): Eric P. Smith[1]
Institution(s): *1. NASA Headquarters*
Contributing team(s): JWST Project Science Team, STScI JWST Mission Office

110.02 – NIRcam-NIRSpec GTO Observations of Galaxy Evolution

The NIRSpec and and NIRCam GTO Teams are planning a joint imaging and spectroscopic study of the high redshift universe. By virtue of planning a joint program which includes medium and deep near- and mid-infrared imaging surveys and multi-object spectroscopy (MOS) of sources in the same fields, we have learned much about planning observing programs for each of the instruments and using them in parallel mode to maximize photon collection time. The design and rationale for our joint program will be explored in this talk with an emphasis on why we have chosen particular suites of filters and spectroscopic resolutions, why we have chosen particular exposure patterns, and how we have designed the parallel observations. The actual observations that we intend on executing will serve as examples of how to layout mosaics and MOS observations to maximize observing efficiency for surveys with JWST.

Author(s): Marcia J. Rieke[10], Pierre Ferruit[3], Stacey Alberts[10], Andrew Bunker[2], Stephane Charlot[5], Jacopo Chevallard[3], Alan Dressler[9], Eiichi Egami[10],Daniel Eisenstein[4], Ryan Endsley[10], Marijn Franx[6], Brenda L. Frye[10], Kevin Hainline[10], Peter Jakobsen[12], Emma Curtis Lake[5], Roberto Maiolino[1], Hans-Walter Rix[7], Brant Robertson[11], Daniel Stark[10], Christina Williams[10], Christopher Willmer[10], Chris J Willott[8]
Institution(s): *1. Cambridge University, 2. Department of Physics, University of Oxford, 3. European Space Agency, 4. Harvard University, 5. IAP, 6. Leiden University, 7. Max Planck Institute for Astronomy , 8. NRC Herzberg, 9. The Carnegie Observatories, 10. Univ. of Arizona, 11. University of California Santa Cruz, 12. University of Copenhagen*

110.03 – MIRI GTO Extragalactic Surveys

The MIRI GTO surveys will focus on the redshift range from 1 to 6. At the lower part of this range, we will conduct a multiband survey of about 30 square arcmin centered on the GOODS-S/HUDF region. We have developed means for a reliable separation of star forming galaxies and active galactic nuclei on the basis of these data. We expect to detect well in all bands about 800 star forming galaxies between redshifts of 1 and 2. We will use the data to determine star formation rates down to 10 solar masses per year for the most distant of these galaxies. The survey area has been set to include 30-50 AGN of known types well-detected at 21 microns with MIRI. The multiband data will let us identify any additional obscured AGN through their emission near 5 microns where star forming SEDs have a minimum. Given the ultradeep radio, optical-UV, and X-ray data in the same field, we expect to derive a complete sample of luminous AGNs and define the characteristics of its members. We will also conduct smaller-area ultra-deep surveys at 5.6 and 7.7 microns. They will detect normal galaxies out to z of 6.5 - 7.5, where they will still provide measurements of tens of them. These data will be used with NIRCam measurements to improve the accuracy of the mass estimates for normal galaxies. The depth and resolution of the MIRI images will far exceed any previous data and hence they also have significant discovery potential.

Author(s): George Rieke[1]
Institution(s): *1. Univ. of Arizona*
Contributing team(s): MIRI Instrument Team

111 – Inner Solar Systems: Super-Earth Orbital Properties: Nature vs. Nurture

Over the past couple decades, thousands of exoplanets have been discovered on orbits interior to 1 AU, from hot Jupiters orbiting close to their host stars to systems of dynamically-packed super-Earths. Despite exquisite observations of individual worlds, statistical analyses of the growing collection of objects, and extensive simulations of their formation and evolution, the origins of inner Solar Systems remain debated. Inner Solar Systems brings together experts from different perspectives to address outstanding questions about the origins of inner solar systems. We focus on questions where there is tension between observations and theory or different models or interpretations. Each panel-based session addresses a single outstanding question and is led by a panel chair who introduces the topic, moderates the discussion among panelists, and engages the audience in identifying the next steps to resolving the question.

111.01 – The Mass Function of Planets

The distribution of orbital period ratios of adjacent planets in extrasolar planetary systems discovered by the Kepler space telescope exhibits a peak near 1.5-2, a long tail of larger period ratios, and a steep drop-off in the number of systems with period ratios below 1.5. We find from these data that the dimensionless orbital separations have an approximately log-normal distribution. Using Hill's criterion for the dynamical stability of two planets, we find that the upper bound on the most common planet-to-star mass ratio is $10^{-3.2}m_*$, about two-thirds of the mass of Jupiter orbiting solar mass stars. Assuming that the mass ratio and the dynamical separation of adjacent planets are independent random variates, and adopting empirical distributions for these, we calculate the planet mass distribution function from the observed distribution of orbital period ratios. We find that the planet mass function is a rolling power law, steeper at higher mass, with an index of approximately -1.2 near jovian planet masses and a shallower index of approximately -0.6 near terrestrial planet masses.

We are grateful for research funding from NSF (grant AST-1312498) and NASA (grant NNX14AG93G).

Author(s): Renu Malhotra[1]
Institution(s): *1. Univ. of Arizona*

111.02 – Consolidating and crushing exoplanets: dynamical instabilities in tightly packed planetary systems

The Kepler mission has revealed that systems of tightly-packed inner planets are fairly common around solar-type stars. The observed systems must be stable for the ages of their host stars (~10^9 years), but some of these systems are close to instability. If one assumes that most planetary systems form with tightly-packed inner planets, then their current absence around some stars could be explained by the destruction of an inner system after a period of meta-stability; in this scendario, the estimated rate at which these systems become unstable is roughly consistent with their current observed frequency. I will disucss how dynamical instabilities in tightly-packed planetary systems might change their architecture and the potential observational consequences of this process.

Author(s): Kathryn Volk[1]
Institution(s): *1. University of Arizona*

111.03 – Jupiter's Grand Attack

The statistics of extrasolar planetary systems indicate that the default mode of planetary formation generates planets with orbital periods shorter than 100 days, and masses substantially exceeding that of the Earth. When viewed in this context, the Solar System, which contains no planets interior to Mercury's 88-day orbit, is unusual. Extra-solar planetary detection surveys also suggest that planets with masses and periods broadly similar to Jupiter's are somewhat uncommon, with occurrence fraction of less than ~ 10%. In this talk, I will present calculations which show that a popular formation scenario for Jupiter and Saturn, in which Jupiter migrates inward from a > 5AU to a ~ 1.5 AU and then reverses direction, can explain the low overall mass of the Solar System's terrestrial planets, as well as the absence of planets with a < 0.4 AU. Jupiter's inward migration entrained s > 10 – 100 km planetesimals into low- order mean-motion resonances, shepherding of order 10 Earth masses of this material into the a ~ 1 AU region while exciting substantial orbital eccentricity (e ~ 0.2 – 0.4). We argue that under these conditions, a collisional cascade will ensue, generating a planetesimal disk that would have flushed any preexisting short-period super-Earth-like planets into the Sun. In this scenario, the Solar System's terrestrial planets formed from gas-starved mass-depleted debris that remained after the primary period of dynamical evolution.

Author(s): Konstantin Batygin[1]
Institution(s): *1. California Institute of Technology*

111.04 – Dynamical Stability and Evolution of Kepler's compact inner multi-planet systems

NASA's Kepler mission has revealed a population of highly compact inner multi-planet systems. These systems, typically consisting of 4-6 super-Earths, feature tight orbital spacing between planets as well as low orbital inclinations (~2 deg.) and eccentricities (~2%). This stands in contrast to Kepler's singles population, which appears to feature higher orbital obliquities and eccentricities, as well as a lower transit timing variation fraction indicative of lower true planet multiplicities.

In this talk, I will present some previous and ongoing research aimed at understanding the dynamical evolution of these Kepler systems. First, I will present

numerical N-body investigations on the long-term stability of multi-planet systems, the results of which suggest that *Kepler's* systems are near the edge of stability. Next, I will discuss some current research on the dynamics of planetary close encounters and collisions, and their implications for the ultimate fate of dynamically unstable multi-planet systems. Finally, I will highlight some recent results on the dynamical stability and evolution of inner multi-planet systems when they are accompanied by external giant planet and/or stellar companions.
Author(s): Bonan Pu[1]
Institution(s): *1. Cornell University*

112 – Plenary Talk: The Universe's Most Extreme Star-forming Galaxies, Caitlin Casey (University of Texas, Austin)

112.01 – The Universe's Most Extreme Star-forming Galaxies

Dusty star-forming galaxies host the most intense stellar nurseries in the Universe. Their unusual characteristics (SFRs=200-2000Msun/yr, Mstar>10^{10} Msun) pose a unique challenge for cosmological simulations and galaxy formation theory, particularly at early times. Although rare today, they were factors of 1000 times more prevalent at z~2-5, contributing significantly to the buildup of the Universe's stellar mass and the formation of high-mass galaxies. At even earlier times (within 1Gyr post Big Bang) they could have played a pivotal role in enriching the IGM. However, an ongoing debate lingers as to their evolutionary origins at high-redshift, whether or not they are triggered by major mergers of gas-rich disk galaxies, or if they are solitary galaxies continually fed pristine gas from the intergalactic medium. Furthermore, their presence in early protoclusters, only revealed quite recently, pose intriguing questions regarding the collapse of large scale structure. I will discuss some of the latest observational programs dedicated to understanding dust-obscuration in and gas content of the early Universe, their context in the cosmic web, and future long-term observing campaigns that may reveal their relationship to `normal' galaxies, thus teaching us valuable lessons on the physical mechanisms of galaxy growth and the collapse of large scale structure in an evolving Universe.
Author(s): Caitlin Casey[1]
Institution(s): *1. University of Texas*

113 – Plenary Talk: Science Highlights from SOFIA, Erick Young (USRA)

113.01 – Science Highlights from SOFIA

SOFIA, the Stratospheric Observatory for Infrared Astronomy, is a joint project between NASA and the German Aerospace Center DLR to provide infrared and sub-millimeter observing capabilities to the worldwide astronomical community. With a wide range of instruments that cover both imaging and spectroscopy, SOFIA has produced unique scientific results that could not be obtained with a ground-based facility. In this talk, I will describe highlights from a range of areas in astronomy. A particular strength of SOFIA is high resolution spectroscopy. In the mid-infrared, the instrument EXES has enabled velocity-resolved observations of solar system, interstellar, and star forming regions. The heterodyne spectrometer GREAT has been a particularly productive instrument on SOFIA, with high resolution studies of the gas in the interstellar medium. With its extremely high spectral resolution, GREAT has allowed dynamical studies of clouds and their interactions. I will highlight observations that demonstrate the infall of material in star-forming regions. SOFIA can go to where the science is. This mobility is important for localized events such as occultations. Results from the recent Pluto occultation campaign will be discussed.
Author(s): Erick T. Young[1]
Institution(s): *1. USRA*

114 – Preparing for JWST Observations Poster Session

114.01 – A Data Simulator Tool for NIRCam

We present a new data simulator tool capable of producing high fidelity simulated data for NIRCam. This simulator produces “raw” multiaccum integrations, each composed of multiple non-destructive detector readouts. This is equivalent to data from real observations prior to the application of any calibration steps.

Our primary motivation for creating this tool is to produce realistic data with which to test the JWST calibration pipeline steps, from basic calibration through the production of mosaic images and associated source catalogs. However, data created from this tool may also be useful to observers wishing to have example data to test custom data reduction or analysis software.

The simulator begins with a real NIRCam dark current integration and adds synthetic astronomical sources. In this way, the simulated integration is guaranteed to contain all of the same noise characteristics and detector effects that will be present in real NIRCam observations. The output format of the simulated data is such that the files can be immediately run through the standard JWST calibration pipelines.

Currently the tool supports the creation of NIRCam imaging and dispersed (wide field slitless) observations, including moving target (non-sidereal tracking) and time series observation data.

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Institution(s): *1. STScI*
Contributing team(s): NIRCam Team at STScI

114.02 – A New Non-Linearity Correction Method for the JWST Near-Infrared Camera

JWST infrared detectors have an intrinsic non-linearity due to the change in PN junction capacitance as charge accumulates in the individual pixel capacitors. Correction of this non-linearity is a fundamental step in the JWST Science Calibration Pipeline. I evaluate a proposed method to calculate a more accurate non-linearity correction for the Near-Infrared Camera (NIRCam) using a function of the ideal linear signal count rate. This algorithm allows the reconstruction of the true linear signal to within 0.2% over ~97% of the full dynamic range, a substantial improvement over the current correction strategy adopted, for example, for the Wide Field Camera 3 infrared channel on Hubble. Using this method, I demonstrate that the coefficients derived to correct a regular ramp (i.e., a sequence of non-destructive samples) are also adequate to reconstruct the true signal in the case of grouped (averaged) samples, characteristic of JWST observations. The robustness of the method is tested using both real data and simulated ramps with different count rates. The new algorithm consistently provides highly accurate non-linearity corrections and can successfully be applied to all 10 NIRCam detectors.

Author(s): Alicia Michelle Canipe[1], Massimo Robberto[1], Bryan Hilbert[1]
Institution(s): *1. Space Telescope Science Institute*

114.04 – High contrast imaging with the JWST-NIRSpec Integral Field Unit

With its integral field unit, the near-infrared spectrograph NIRSpec on JWST will allow to measure high-resolution spectra into the 3-5 µm range with an increased sensitivity over ground-based systems. This capability will considerably extend our knowledge of brown dwarfs and bright exoplanets at large separations from their host star. But because there is not any coronagraph on NIRSpec, the performance in term of contrast at close separation will be extremely limited. In this communication, we explore possibilities to further push this limitation by comparing different observing strategies and associated post-processing techniques.

Author(s): Marie Ygouf[2], Charles A. Beichman[3], Klaus W. Hodapp[1], Thomas L. Roellig[4]
Institution(s): *1. Institute for Astronomy, 2. IPAC/Caltech, 3. JPL, 4. NASA Ames*
Contributing team(s): NIRCam GTO

114.05 – JWST NIRCam WFSS Ice Feature Spectroscopy in Nearby Molecular Cores

In molecular clouds above a few magnitudes of total visual extinction, some components of the molecular gas freeze out on the surfaces of dust grains. These ice mantles around dust grains are the site of complex surface chemistry that leads to the formation of simple organic molecules in these mantles. The icy surfaces also facilitate the coaggulation of the dust particles, setting the stage for grain growth and ultimately the formation of planetary bodies.

As part of the JWST NIRCam GTO program, we plan to observe a selection of small molecular cores using the wide field grism spectroscopy mode of NIRCam.

This poster presents the results of a preliminary study of several candidate molecular cores using UKIRT, *Spitzer* IRAC, IRTF SpeX, Keck MOSFIRE and Subaru MOIRCS data.

After the prelimary studies we have selected three molecular cores in different evolutionary stages for the GTO program: B68, a quiescent molecular core, LDN 694-2, a collapsing pre-stellar core, and B335, a protostellar core. All these cores are seen against a dense background of stars in the inner Galaxy and offer the opportunity for spatially well resolved mapping of the ice feature distribution. We will obtain slitless grism spectroscopy in six filters covering the features of H_2O, CO_2, CO, CH_3OH, and the XCN feature. Simulations using aXeSIM have shown that spectrum overlap will occur in a fraction of the spectra, but will not be a prohibitive problem.

Our poster will discuss the details of observations planned out in the APT system.

Author(s): Laurie Chu[3], Klaus W. Hodapp[3], Marcia J. Rieke[2], Michael Meyer[4], Thomas P. Greene[1]
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Contributing team(s): JWST NIRCam Science Team

114.06 – JWST NIRCam GTO Program: IFU Spectroscopy of Spatially Resolved Exoplanets with NIRSpec

Our goal is to understand the atmospheric condition of self-luminous, fairly young companions below the deuterium burning mass limit.Can metallicity or isotopic composition be determined and do those give clues about the formation mechanism of these exoplanets?

This JWST GTO observing program concentrates on the 3.0 – 5.0 µm wavelength range that is poorly accessible from the ground due to high thermal background and poor atmospheric transmission and where JWST has a substantial advantage.

We have selected 6 Objects for this program, ranging from closely spaced, high-contrast cases to widely separated exoplanets.HR 8799 b, c, and d, 2MASS J22362452+4751425, HD106906 b, and GU Psc b.

The closely spaced exoplanets require careful PSF subtraction, which we plan to do by a combination of azimuthal differential imaging using two roll angles of JWST, and spectral differential imaging in the NIRSpec IFU data cubes.

The NIRSpec IFU has lower throughput than the long-slit mode due to the additional optics required for the slicing of the 2D image and re-arranging into a long-slit format. However, this is less important than the ability to subtract the speckle pattern of the host star that the IFU allows. All our objects are quite bright, well above the empty-field-and-low-background NIRSpec sensitivity limits.

We will use the NIRSpec IFU in R=1000 mode with the G395M grating and F290LP filter. Detector readout mode is NRS, 8 groups, 1 integration arranged in a 9-position small cycling pattern. The total exposure time per object and roll angle is 3440s, including a MSA leakage calibration exposure.

Our poster will present the details of these observations planned out in the APT.

Author(s): Klaus W. Hodapp[4], Charles A. Beichman[1], Thomas P. Greene[2], Adam Seth Burrows[3], Marie Ygouf[1]
Institution(s): *1. IPAC, 2. NASA Ames Research Center, 3. Princeton University, 4. Univ. of Hawaii*
Contributing team(s): NIRCam Science Team

114.07 – A JWST NIRCam Coronagraphic Imaging Survey of Nearby Young M Dwarfs

The population of giant planets on wide orbits around low-mass M dwarf stars is poorly understood. Transit, radial velocity and microlensing surveys provide population constraints and occurrence rate estimates within 10 AU, but current ground based imaging struggles to probe below 1 Jupiter mass at larger separations. In the vicinity of the closest, youngest M dwarfs, the unprecedented sensitivity of NIRCam coronagraphic imaging on the JWST provides direct access to lower-mass gas-giants beyond 10 AU. Survey simulations reveal that 3-5 micron imaging is sensitive to sub-Jupiter mass planets and pushes into the ice-giant mass regime around the most favorable targets. Following our simulations, we have designed a NIRCam GTO program to perform deep, dual-band coronagraphic imaging on a sample of the closest youngest M dwarfs. Our program will use the round MASK430R coronagraph with both the F444W and F322W2 filters and include telescope rolls for PSF subtraction. The dual-band imaging approach allows for color-based rejection of stellar and galactic background contaminants. Such observations will provide the first limits on the presence of sub-Jupiter mass planets in the outskirts of these stellar systems, provide constraints on the peak of the planet surface density distribution, and probe the separation of the primordial CO ice line, the hypothesized venue for ice-giant formation.

Author(s): Joshua E. Schlieder[4], Michael Meyer[7], Charles A. Beichman[3], Maddalena Reggiani[6], Sebastian Daemgen[2], Jarron Leisenring[5], Marie Ygouf[1]
Institution(s): *1. Caltech/IPAC, 2. ETH Zurich, 3. JPL, 4. NASA GSFC, 5. University of Arizona, 6. University of Liege, 7. University of Michigan*

114.08 – Lessons from Coronagraphic Imaging with HST that may apply to JWST

One of the major capabilities offered by JWST is coronagraphic imaging from space, covering the near through mid-IR and optimized for study of planet formation and the evolution of planetary systems. Planning for JWST has resulted in expectations for instrument performance, observation strategies and data reduction approaches. HST with 20 years of coronagraphic imaging offers some experience which may be useful to those planning for JWST. 1) Real astronomical sources do not necessarily conform to expectations. Debris disks may be accompanied by more distant material, and some systems may be conspicuous in scattered light when offering only modest IR excesses. Proto-planetary disks are not constantly illuminated, and thus a single epoch observation of the source may not be sufficient to reveal everything about it. 2) The early expectation with NICMOS was that shallow, 2-roll observations would reveal a wealth of debris disks imaged in scattered light, and that only a limited set of PSF observations would be required. Instead, building up a library of spatially resolved disks in scattered light has proven to require alternate observing strategies, is still on-going, and has taken far longer than expected. 3) A wealth of coronagraphic options with an instrument may not be scientifically informative, unless there is a similar time investment in acquisition of calibration data in support of the science observations. 4) Finally, no one anticipated what can be gleaned from coronagraphic imaging. We should expect similar, unexpected, and ultimately revolutionary discoveries with JWST.

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114.09 – JWST Mid-Infrared Instrument Data Reduction Pipeline and Products

We present the James Webb Space Telescope Mid-Infrared Instrument (JWST/MIRI) data reduction pipeline and resulting data products. MIRI operates from 5 to 28.5 microns and provides imaging, coronagraphy, low-resolution spectroscopy (LRS), and medium-resolution spectroscopy (MRS) via an integral field unit.

The MIRI pipeline is designed to maximize the scientific return from the instrument by providing high-level data products. The pipeline is divided into three stages: 1) raw to slope image, 2) calibrated slope image, 3) high quality final data products. The final data products include calibrated mosaics for imaging observations, PSF subtracted images for coronograph observations, extracted spectra for LRS observations, and spectral cubes for MRS observations.

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Contributing team(s): MIRI Team

114.10 – JWST Point Spread Function Quality and Stability: Integrated Modeling, Ground Testing, and Space Validation

The James Webb Space Telescope (JWST) is a cryogenic large (6.5 m) segmented aperture telescope with science instruments that cover the near- and mid-infrared from 0.6-27 microns. The large aperture not only provides high photometric sensitivity, but it also enables high angular resolution across the bandpass, with a diffraction limited point spread function (PSF) at wavelengths longer than 2 microns. The JWST PSF quality and stability are intimately tied to the science capabilities as it is convolved with the astrophysical scene. However, the PSF evolves at a variety of timescales based on telescope jitter and thermal distortion as the observatory attitude is varied. We present the image quality and stability requirements, recent predictions from integrated modeling, measurements made during ground-based testing, and performance characterization activities that will be carried out as part of the commissioning process.

Author(s): Michael W. McElwain[2], Charles W. Bowers[2], Timothy Carnahan[2], Randy A. Kimble[2], Paul Lightsey[1], Peiman Maghami[2], David Mustelier[3],Malcolm B. Niedner[2], Marshall D. Perrin[4], Laurent Pueyo[4], Kyle Van Gorkom[4], Erin C. Smith[2], Gregory Walsh[2]
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115 – Astronomy Education: Research, Practice, and Outreach Across the Human Continuum Poster Session

115.01 – The Quantitative Reasoning for College Science (QuaRCS) Assessment in non-Astro 101 Courses II

The Quantitative Reasoning for College Science (QuaRCS) Assessment[1] aims to measure the pre-algebra mathematical skills that are often part of "general education" science courses like Astro 101. In four majors STEM classes, we report comparisons between QuaRCS metrics, ACT math, GPAO, and the course grade. In three of four classes QuaRCS QR score and ACT math were statistically significantly correlated (with r~.6), however in the fourth course — a senior-level microbiology course— there was no statistically significantly correlation (in fact, r<0). In all courses —even in courses with seemingly little quantitative content— course grade was statistically significantly correlated to GPAO and QR. A QuaRCS metric aiming to report the students belief in the importance of math in science was seen to grow with the course level. Pre/post QuaRCS testing in Physics courses showed fractional sigma gains in QR, self-estimated math fluency and math importance, but not all of those increases were statistically significant. Using a QuaRCS map relating the questions to skill areas, we found graph reading, percentages, and proportional reasoning to be the most misunderstood skills in all four courses.

[1] QuaRCS, Follette, et al., 2015, DOI: http://dx.doi.org/10.5038/1936-4660.8.2.2

Author(s): Thomas W. Kirkman[2], Ellen Jensen[1]
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115.02 – Improve ay101 teaching by single modifications versus unchanged controls: statistically-supported examples

The two main purposes of this paper on improving Ay101 courses are presentations of (1) some very effective single changes and (2) a method to improve teaching by making just single changes which are evaluated statistically versus a control group class. We show how simple statistical comparison can be done even with Excel in Windows. Of course, other more sophisticated and powerful methods could be used if available. One of several examples to be discussed on our poster is our modification of an online introductory astronomy lab course evaluated by the multiple choice final exam. We composed questions related to the learning objectives of the course modules (LOQs). Students could “talk to themselves” by discursively answering these for extra credit prior to the final. Results were compared to an otherwise identical previous unmodified class. Modified classes showed statistically much better final exam average scores (78% vs. 66%). This modification helped those students who most need help. Students in the lower third of the class preferentially answered the LOQs to improve their scores and the class average on the exam. These results also show the effectiveness of relevant extra credit work. Other examples will be discussed as specific examples of evaluating improvement by making one change and then testing it versus a control. Essentially, this is an evolutionary approach in which single favorable “mutations” are retained and the unfavorable removed. The temptation to make more than one change each time must be resisted!

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115.03 – Improving Discussion in Astronomy Courses Taught Online

Astronomy courses that are either hybrid in nature or offered in a completely online format are becoming more common at colleges and universities. In particular, faculty members at small colleges are being encouraged to develop courses that can be taught online in order to give students increased flexibility in scheduling classes and reach a separate population of learners. For instructors accustomed to teaching students in person using plenty of interaction, making the switch to teaching even one online course a year can be challenging. However, some topics are developing so rapidly (exoplanets) that it is difficult to imagine having students rely on a standard textbook at all, and the use of online resources become essential. Here, we describe methods used to promote discussion, evaluate its content and effectively incorporate the use of recently released articles in order to keep students engaged. We present efforts to produce a lively classroom atmosphere centered on recent advances and several debated topics. Lastly, we report on successes, challenges and plans for improving online courses in the future.

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Institution(s): *1. Hartwick College*

115.05 – *Astronomy4Kids*: A new, online, STEM-focused, video education outreach program

Recent research indicates significant benefits of early childhood introductions to language, mathematics, and general science concepts. Specifically, a child that is introduced to a concept at a young age is more prepared to receive it in its entirety later. *Astronomy4Kids* was created to bring science, technology, engineering, and math (STEM) concepts to the youngest learners (those under the age of eight, or those from pre-school to about second-grade). The videos are presented in a succinct, one-on-one manner, and provide a creative learning environment for the viewers. Following the preschool education video principles established by Fred Rogers, we hope to give young children access to an expert astronomer who can explain things simply and sincerely. We believe presenting the material in this manner will make it engaging for even the youngest scholar and available to any interested party. The videos can be freely accessed at www.astronomy4kids.net.

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Institution(s): *1. Astronomy4Kids*

115.06 – Aquarius-Pisces Constellation Boundary Update

Observation, mapping and study of Galaxy Stars has provided humanity direction, foundation, clarity and understanding through the ages.

Human civilization advances itself using increasing intelligence and knowledge to develop tools and know how, the science of constellation star maps included: All that has been created by humanity, is to serve humanity.

When people continue to use constellation star maps that no longer serve people effectively, the maps are updated, as is now the Aquarius-Pisces Constellation Boundary Update (APCBU), which marks 2000 as the year the Sun is in Aquarius at the vernal equinox.

The 21st Century APCBU accounts for and incorporates science factors of precession, relativity and galacticity for professional astronomers, and social imperatives of increasing freedom, liberation and egalitarian culture for the 7.5 billion people of Earth.

Twenty years into this first century of a new millennium and a new age is an effective time for an APCBU of such elegant simplicity that it changes less than 0.1% of the area of the IAU 1930 official constellation map, which marks 2597 about the year the Sun is in Aquarius at the time of the vernal equinox.

The 21st Century APCBU results provide clarity and direction for humanity's next 2,000 years, if not 10,000 or 12,000 years, and advance the official astronomy / science start of the Aquarius Age -- long anticipated, desired, and imperative, especially in America -- by some 600 years.

How much attention is increasingly focused on this region of the sky -- such as the recent discovery of 7 Earth-like worlds orbiting the Trappist-1 star in the Aquarius constellation -- will be an epochal 21st Century phenomenon of human science, society, and starlife.

Author(s): Steve Durst[1]
Institution(s): *1. Space Age Publishing Company*

115.08 – Astrobites: Blogging Astrophysics Research, Bringing it to the Classroom, and beyond

Transitioning from undergraduate studies to a career in scientific research is not without its difficulties. Astrobites (astrobites.com) is a graduate student-organized website that aims to decipher the research process in astrophysics and present the latest discoveries in form of daily digestible blog posts. Astrobites posts paint vivid mental pictures of diverse research topics without jargon or extensive presumed knowledge, helping readers to make the connections between topics. Besides summarizing research papers, our posts feature reviews on selected subjects, sharing in career development, live-blogging in conferences, and keynote speakers' personal encounters with science! The accessibility of Astrobites attracts readers beyond undergraduate students, from professional astrophysicists exploring unfamiliar territory outside of their research to science educators looking for exciting and topical ideas for lesson plans. We will present our goals, readership, latest endeavors, and future initiatives.

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Contributing team(s): Astrobites Team

116 – Societal Matters Poster Session

116.01 – The AAS Working Group on Accessibility and Disability (WGAD) Year 1 Highlights and Database Access

The AAS Working Group on Accessibility and Disability (WGAD) was formed in January of 2016 with the express purpose of seeking equity of opportunity and building inclusive practices for disabled astronomers at all educational and career stages. In this presentation, we will provide a summary of current activities, focusing on developing best practices for accessibility with respect to astronomical databases, publications, and meetings. Due to the reliance of space sciences on databases, it is important to have user centered design systems for data retrieval. The cognitive overload that may be experienced by users of current databases may be mitigated by use of multi-modal interfaces such as xSonify. Such interfaces would be in parallel or outside the original database and would not require additional software efforts from the original database. WGAD is partnering with the IAU Commission C1 WG Astronomy for Equity and Inclusion to develop such accessibility tools for databases and methods for user testing. To collect data on astronomical conference and meeting accessibility considerations, WGAD solicited feedback from January AAS attendees via a web form. These data, together with upcoming input from the community and analysis of accessibility documents of similar conferences, will be used to create a meeting accessibility document. Additionally, we will update the progress of journal access guidelines and our social media presence via Twitter. We recommend that astronomical journals form committees to evaluate the accessibility of their publications by performing user-centered usability studies.

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117 – Instrumentation Poster Session

117.01 – Mechanical Designs and Developement of Advanced ACT: A Transfomative Upgrade to the ACTPol Receiver on the Atacama Cosmology Telescope.

The Atacama Cosmology Telescope is a six-meter diameter telescope located at 17,000 feet (5,200 meters) on Cerro Toco in the Andes Mountains of northern Chile. The next generation Advanced ACT (AdvACT) experiment is currently underway and will consist of three multichroic TES bolometer arrays operating together, totaling 5800 detectors on the sky. Each array will be sensitive to two frequency bands: a high frequency (HF) array at 150 and 230 GHz, two middle frequency (MF) arrays at 90 and 150 GHz, and a low frequency (LF) array at 28 and 41 GHz. The AdACT detector arrays will feature a revamped design when compared to ACTPol, including a transition to 150mm wafers equipped with multichroic pixels, allowing for a more densely packed focal plane. Each set of detectors consists of a feedhorn array of stacked silicon wafers which form a corrugated profile leading to each pixel. This is then followed by a four-piece detector stack assembly of silicon wafers which includes a waveguide interface plate, detector wafer, backshort cavity plate, and backshort cap. Each array is housed in a custom designed structure manufactured out of gold-plated, high purity copper. In addition to the detector array assembly, the array package also encloses the majority of our readout electronics. We present the full mechanical design of the AdvACT HF and MF detector array packages along with a detailed look at the detector array assemblies. We also highlight the use of continuously rotating warm half-wave plates (HWPs) at the front of the AdvACT receiver. We review the design of the rotation system and also early pipeline data analysis results. This experiment will also make use of extensive hardware and software previously developed for ACT, which will be modified to incorporate the new AdvACT instruments. Therefore, we discuss the integration of all AdvACT instruments with pre-existing ACTPol infrastructure.

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Contributing team(s): The Advanced ACT Collaboration, NASA Space Technology Research Fellowship

117.02 – CRIRES$^+$: A Cross-dispersed High-resolution Infrared Spectrograph for ESO's VLT

CRIRES$^+$ is a major upgrade to the former CRyogenic high resolution Infra-Red Echelle Spectrograph of ESO's 8.2m Very Large Telescope. The major science drivers for this upgrade are the confirmation and characterization (e.g. determination of the mass) of rocky planets in the so-called habitable zone of M-dwarf stars via radial velocity measurements, the characterization of exoplanet atmospheres, and the study of magnetic fields in low mass stars and brown dwarfs. CRIRES+ will maintain the high resolving power (R = 100,000) of its predecessor in the *Y*, *J*, *H*, *K*, *L* and *M* bands, but it will include the following improvements: 1) CRIRES+ will be cross-dispersed recording 8-9 diffraction orders at a time, increasing the observing efficiency approximately by an order of magnitude. 2) New detectors with better sensitivity and cosmetics over the old devices. 3) A new gas absorption cell for improved wavelength calibration. This along with the increased wavelength coverage should yield a radial velocity measurement precision to better than 2-5 m/s in K-band. In addition, in *Y* to *K* bands, a new Fabry-Perot etalon device will ensure a precision of 100 m/s. 4) A polarimetric unit which will measure both circular and linear polarization. We present the current status and schedule of the project. The instrument is currently scheduled to be installed at the telescope beginning 2018.

Author(s): Artie Hatzes[1]
Institution(s): *1. Thüringer Landessternwarte Tautenburg*
Contributing team(s): CRIRES+ Team

117.03 – Commissioning of the new GMOS-N Hamamatsu CCDs

We report on the commissioning of the new Hamamatsu fully-depleted CCDs for GMOS-N, installed in the instrument in February 2017. The Hamamatsu detectors replace the e2v deep depletion devices which had been in operation since 2011. The new GMOS-N detector array is expected to provide improved red sensitivity compared to the e2v devices at wavelengths longer than ~900 nm. The commissioning of the new detector array for GMOS-N marks the final step in upgrading the two GMOS instruments at Gemini North and South with Hamamatsu detectors.

Author(s): Julia Scharwaechter[1], Kristin Chiboucas[1], German Gimeno[2], Luc Boucher[2], John White[1], Eduardo Tapia[1], Michael Lundquist[1], Mathew Rippa[1],Kathleen Labrie[1], Richard Murowinski[1], Manuel Lazo[2], Jennifer Miller[1]
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117.04 – Fifteen 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 fifteen years, subsequent to its Servicing Mission 3B installation in 2002. The once defunct ACS Wide Field Channel (WFC) has now been operating almost twice as long (>8yrs) 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.

The past year has seen several advancements in ACS data acquisition and calibration capabilities: the most widespread changes since shortly after SM4. We review these recent developments that enable the continued high performance of this instrument, including both the WFC and the Solar Blind Channel (SBC). Highlights
include: 1) implementaton of new WFC subarray modes to allow for more consistent high-fidelity calibration; 2) a thorough modernization of the original pixel-based correction of WFC charge-transfer efficiency decline; 3)
"save the pixels" initiatives resulting in much less WFC bad-pixel flagging via hot-pixel stability analyses and readout-dark modeling; and 4) a new initiative to provide improved PSF estimates via empirical fitting to the full ACS archive of nearly 200,000 images.

Author(s): Norman A. Grogin[1]
Institution(s): *1. Space Telescope Science Institute*
Contributing team(s): Advanced Camera for Surveys Instrument Team

117.05 – New Data Reduction and Analysis Documentation for HST and ACS

As a service to HST users, and as STScI moves from supporting an IRAF/PyRAF environment for HST data reduction and analysis to one involving more direct usage of Python for both HST and JWST, our documentation must follow suit. We are in the process of revising our documentation for both HST and ACS to reflect this new reality. Although many tasks needing to be done in data reduction and analysis remain the same except for now being accomplished more directly by Python scripts, etc., some preferred ways of doing things may also change in some cases, especially where new possibilities for improvements exist. Along with a greater reliance on often free, open source, community-based software routines and new methods for distributing and upgrading software, there are also more new tools for data visualization, and for presenting catalogs, tabular, and textual information in ways which allow for things like the interactive comparison of or integration of multiple datasets, and easier ways of selecting subsamples from tables and highlighting them in plots, interactively linking tables with graphical data, etc. in more forms. We will present some of our plans for the updated documentation and some of these features which are being explored for further use.

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Institution(s): *1. STScI*
Contributing team(s): STScI ACS Team, STScI Science Software Branch

117.06 – Pixel Stability in HST Advanced Camera for Surveys Images

Excess thermal energy present in a Charged Coupled Device (CCD) can result in additional electrical current that is propagated into individual pixels in an exposure. This excess signal from the CCD itself can be persistently existent through multiple exposures and can have an adverse effect on the detectors science performance unless properly flagged and corrected for. The traditional way to correct for this extra charge is to take occasional long-exposure images with the camera shutter closed to map the location of these pixels. These images, generally referred to as “dark” images, allow for the measurement of the thermal-electron contamination present in each pixel of the CCD lattice. This "dark current" can then be subtracted from the science images by re-scaling the dark to the science exposure times. Pixels that have signal above a certain threshold are traditionally marked as “hot” and flagged in the data quality array. Many users will discard these pixels as being bad because of this extra current. However, these pixels may not be "bad" in the traditional sense that they cannot be reliably dark-subtracted. If these pixels are shown to be stable over an anneal period, the charge can be properly subtracted and the extra Poisson noise from this hot pixel’s dark current can be taken into account. Here we present the results of a pixel history study that analyzes every individual pixel of the Hubble Space Telescope's (HST) Advanced Camera for Surveys (ACS) Wide Field Channel (WFC) CCDs over time and allows pixels that were previously marked as bad to be brought back into the science image as a reliable pixel.

Author(s): David Borncamp[1], Norman A. Grogin[1], Matthew Bourque[1], Sara Ogaz[1]
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117.07 – Improving Image Drizzling in the HST Archive: Advanced Camera for Surveys

The Mikulski Archive for Space Telescopes (MAST) pipeline performs geometric distortion corrections, associated image combinations, and cosmic ray rejections with AstroDrizzle on Hubble Space Telescope (HST) data. The MDRIZTAB reference table contains a list of relevant parameters that controls this program. This document details our photometric analysis of Advanced Camera for Surveys Wide Field Channel (ACS/WFC) data processed by AstroDrizzle. Based on this analysis, we update the MDRIZTAB table to improve the quality of the drizzled products delivered by MAST.

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

117.08 – Extreme charge-trapping by pixels in Hubble's ACS/WFC detectors

We investigate the properties of sink pixels in the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC) detector. These pixels likely contain extra charge traps and therefore appear anomalously low in images with relatively high backgrounds. We identify sink pixels in the average short (0.5-second) dark image from each monthly anneal cycle, which, since January 2015, have been post-flashed to a background of about 60 e-. Sink pixels can affect the pixels immediately above and below them in the same column, resulting in high downstream pixels and low trails of upstream pixels. We determine typical trail lengths for sink pixels of different depths at various background levels. We create a reference image, one for each anneal cycle since January 2015, that will be used by CALACS to flag sink pixels and the adjacent affected pixels in science images.

Author(s): Jenna E. Ryon[1], Norman A. Grogin[1]
Institution(s): *1. Space Telescope Science Institute*
Contributing team(s): ACS Team

117.09 – New Time Dependent Sensitivity Corrections and Updated Flat Fields for the ACS/SBC

The sensitivity of the Solar Blind Channel on the Advanced Camera for Surveys changes with time. Until now there was no correction available for this effect. Here we present the new corrections, derived for all the imaging filters using observations that date back to installation, more than 15 years worth of data. The sensitivity can now be continuously monitored and the correction updated as necessary. Additionaly, we present a new set of flat fields for all imaging filters. These are necessary because of the previous discovery of a change in the high frequency pattern in the flats currently in use. The new flats were derived using an improved algorithm than what was used for the previous versions, employing MCMC fitting techniques.

Author(s): Roberto J. Avila[1], Diana Kossakowski[2]
Institution(s): *1. Space Telescope Science Institute, 2. University of California, Berkeley*

117.10 – Improvements to the FUV and NUV Wavelength Calibrations of the Cosmic Origins Spectrograph (COS)

The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope in 2009 during Servicing Mission 4. Since then, the teams at the Space Telescope Science Institute have striven to provide the highest quality scientific products to the community. Over the past two years the COS team has been implementing improved wavelength calibrations for both the FUV and NUV channels. Here we present the methodology and current results behind these new wavelength calibration solutions.

Author(s): Rachel Plesha[1], Thomas B. Ake[1], Gisella De Rosa[1], Cristina M. Oliveira[1], Steven V. Penton[1], Julia Roman-Duval[1], Paule Sonnentrucker[1]
Institution(s): *1. Space Telescope Science Institute*

117.11 – Using Dark Images to Characterize the Stability of Pixels in the WFC3/UVIS Detector

The Ultraviolet-Visible (UVIS) detector on board the Hubble Space Telescope's (HST) Wide Field Camera 3 (WFC3) instrument has been acquiring 'dark' images on a daily basis since its installation in 2009. These dark images are 900 second exposures with the shutter closed as to measure the inherent dark current of the detector. Using these dark exposures, we have constructed 'pixel history' images in which a specific column of the detector is extracted from each dark and placed into a new time-ordered array. We discuss how the pixel history images are used to characterize the stability of each pixel over time, as well as current trends in the WFC3/UVIS dark current.

Author(s): Matthew Bourque[1], David Borncamp[1], Sylvia M. Baggett[1], Norman A. Grogin[1]
Institution(s): *1. Space Telescope Science Institute*
Contributing team(s): WFC3 Team

117.12 – Updated Status and Performance at the Fourth HST COS FUV Lifetime Position

To mitigate the adverse effects of gain sag on the spectral quality and accuracy of Hubble Space Telescope's Cosmic Origins Spectrograph FUV observations, COS FUV spectra will be moved from Lifetime Position 3 (LP3) to a new pristine location on the detectors at LP4 in July 2017. To achieve maximal spectral resolution while preserving detector area, the spectra will be shifted in the cross-dispersion (XD) direction by -2.5" (about -31 pixels) from LP3 or -5" (about 62 pixels) from the original LP1. At LP4, the wavelength calibration lamp spectrum can overlap with the previously gain-sagged LP2 PSA spectrum location. If lamp lines fall in the gain sag holes from LP2, it can cause line ratios to change and the wavelength calibration to fail. As a result, we have updated the Wavecal Parameters Reference Table and CalCOS to address this issue. Additionally, it was necessary to extend the current geometric correction in order to encompass the entire LP4 location. Here we present 2-D template profiles and 1-D spectral trace centroids derived at LP4 as well as LP4-related updates to the wavelength calibration, and geometric correction.

Author(s): Joanna M. Taylor[1], Gisella De Rosa[1], Mees B. Fix[1], Andrew Fox[1], Nick Indriolo[1], Bethan James[1], Robert I. Jedrzejewski[1], Cristina M. Oliveira[1],Steven V. Penton[1], Rachel Plesha[1], Charles R. Proffitt[1], Marc Rafelski[1], Julia Roman-Duval[1], David J. Sahnow[1], Elaine M. Snyder[1], Paule Sonnentrucker[1],James White[1]
Institution(s): *1. Space Telescope Science Institute*

117.13 – Hubble's New "Program of Last Resort"

Despite the best efforts of the Hubble schedulers to allocate every last orbit, a small but persistent fraction (~2–3%) of the orbits go unused. Salvaging this unused observing time presents an opportunity for the Institute to benefit the astronomical community. The Institute's Hubble Mission Office has initiated a pilot, ultra-low priority SNAP program (14840, PI: Bellini) in Cycle 24, with the goal of taking useful data in Hubble's orbits that absolutely no other program is able to use.

The initial target list is drawn from HST-unobserved, moderately large and bright NGC/IC galaxies that are "uniformly" distributed across the sky. All targets are identically imaged with two dithered 337-second exposures through the F606W filter of the ACS/WFC. The poster describes the target-selection criteria and gives an update of the current status of this ongoing program.

Author(s): Andrea Bellini[1], Norman A. Grogin[1], Thomas M. Brown[1]
Institution(s): *1. STScI*

117.14 – Simulations of JWST/NIRISS Modes for General Observers

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 on-board 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 present realistic simulations of observations through each of these modes in order to stimulate the General Observer community to consider how NIRISS might help to achieve their scientific goals.

Author(s): Catherine Gosmeyer[1], Loic Albert[2], Gabriel Brammer[1], Joe Filippazzo[1], Alexander W. Fullerton[1], Alexandra Greenbaum[3], Jason Rowe[2],JOHANNES SAHLMANN[1], Anand Sivaramakrishnan[1], Deepashri G. Thatte[1], Kevin Volk[1]
Institution(s): *1. Space Telescope Science Institute, 2. Université de Montréal, 3. University of Michigan*

117.15 – Arcus: Exploring the Formation and Evolution of Clusters, Galaxies, and Stars

The Large Scale Structure (LSS) of the Universe grew via the gravitational collapse of dark matter, but the visible components that trace the LSS–galaxies, groups and clusters–have a more complex history. Their baryons experience shock heating, radiative cooling and feedback from black holes and star formation, which leave faint signatures of hot (T~10^5-10^8 K), metal-enriched gas in the interstellar and intergalactic media (ISM and IGM). While recent Planck and X-ray studies support this scenario, no current mission possesses the instrumentation necessary to provide direct observational evidence for these "missing baryons." Arcus, a proposed MIDEX mission, leverages recent advances in critical-angle transmission (CAT) gratings and silicon pore optics (SPOs), using CCDs with strong Suzaku heritage and electronics based on the Swift mission; both the spacecraft and mission operations reuse highly successful designs. To be launched in 2023, Arcus will be the only observatory capable of studying, in detail, the hot galactic and intergalactic gas–the dominant baryonic component in the present-day Universe and ultimate reservoir of entropy, metals and the output from cosmic feedback. Its superior soft X-ray sensitivity will complement the forthcoming post-Hitomi and Athena calorimeters, which will have comparably high spectral resolution above 2 keV but poorer spectral resolution than XMM or Chandra in the Arcus bandpass.

Author(s): Randall K. Smith[1]
Institution(s): *1. Smithsonian Astrophysical Observatory*
Contributing team(s): Arcus Collaboration

117.16 – Highly Adjustable Systems: An Architecture for Future Space Observatories

Mission costs for ground breaking space astronomical observatories are increasing to the point of unsustainability. We are investigating the use of adjustable or correctable systems as a means to reduce development and therefore mission costs. The poster introduces the promise and possibility of realizing a "net zero CTE" system for the general problem of observatory design and introduces the basic systems architecture we are considering. This poster concludes with an overview of our planned study and demonstrations for proving the value and worth of highly adjustable telescopes and systems ahead of the upcoming decadal survey.

Author(s): Jonathan Arenberg[2], Alberto Conti[2], David Redding[1], Charles R. Lawrence[1], Roman Hachkowski[2], Robert Laskin[1], John Steeves[1]
Institution(s): *1. Jet Propulsion Laboratory, 2. Northrop Grumman*

117.18 – Unlocking the astrometric power of the HST imaging instruments

The Hubble Space Telescope can yield sub-milli-arc-second accuracy in differential astrometry and 0.1% precision in photometry. To achieve such high accuracy, a number of instrumental issues and systematics must be understood and accounted for. The most important are: stability of the geometric distortion with time and across the filters, understanding small pixel-grid irregularities at various scales. These systematics may affect the measurements of apparent magnitudes, positions, parallaxes, and proper motions. In addition, they worsen the appearance of combined dithered images and the alignment of cross-instrument frames. A deep understanding of the current HST imaging instruments is beneficial to the future space missions such as JWST and WFIRST.

Author(s): Vera Kozhurina-Platais[1], David Borncamp[1], Roberto J. Avila[1], Norman A. Grogin[1], Elena Sabbi[1], Linda J. Smith[1]
Institution(s): *1. STScI*

117.19 – Spitzer/JWST Cross Calibration: IRAC Observations of Potential Calibrators for JWST

We present observations at 3.6 and 4.5 microns using IRAC on the Spitzer Space Telescope of a set of main sequence A stars and white dwarfs that are potential calibrators across the JWST instrument suite. The stars range from brightnesses of 4.4 to 15 mag in K band. The calibration observations use a similar redundancy to the observing strategy for the IRAC primary calibrators (Reach et al. 2005) and the photometry is obtained using identical methods and instrumental photometric corrections as those applied to the IRAC primary calibrators (Carey et al. 2009). The resulting photometry is then compared to the predictions based on spectra from the CALSPEC Calibration Database (http://www.stsci.edu/hst/observatory/crds/calspec.html) and the IRAC bandpasses. These observations are part of an ongoing collaboration between IPAC and STScI investigating absolute calibration in the infrared.

Author(s): Sean J. Carey[1], Karl D. Gordon[3], Patrick Lowrance[1], James G. Ingalls[1], William J. Glaccum[1], Carl J. Grillmair[1], Jessica E Krick[1], Seppo J. Laine[1], Giovanni G. Fazio[1], Joseph L. Hora[2], Ralph Bohlin[3]
Institution(s): *1. Caltech/IPAC-Spitzer, 2. Harvard-Smithsonian, CfA, 3. STScI*

117.20 – TRAO Multibeam Receiver System and Key Science Programs

Taeduk Radio Astronomy Observatory (TRAO) is now equipped with a main controling computer with VxWorks operating system, a new receiver system, and a new backend system. The new receiver system(TRAO-SEQUOIA) 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 (86~110 GHz) to 450 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 of the receiver. Radome replacement was completed successfully as of February 2017. In addition, a new servo system will be installed in 2017 summer. We provide OTF (On-The-Fly) as a main observing mode, and position switching mode is available as well. The backend system (FFT spectrometer) provides the 4096x2 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 46% – 54% (with less than 2% error) between 86 and 115 GHz bands and 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.

Author(s): Youngung Lee[1]
Institution(s): *1. Korea Astronomy and Space Science Institute*

117.21 – Center Finding Algorithm on slit mask point source for IGRINS (Immersion GRating INfrared Spectrograph)

We developed an observation control software for the IGRINS (Immersion Grating Infrared Spectrograph) silt-viewing camera module, which points the astronomical target onto the spectroscopy slit and sends tracking feedbacks to the telescope control system (TCS). The point spread function (PSF) image is not following symmetric Gaussian profile. In addition, bright targets are easily saturated and shown as a donut shape. It is not trivial to define and find the center of the asymmetric PSF especially when most of the stellar PSF falls inside the slit. We made a center balancing algorithm (CBA) which derives the expected center position along the slit-width axis by referencing the stray flux ratios of both upper and lower sides of the slit. We compared accuracies of the CBA and those of a two-dimensional Gaussian fitting (2DGA) through simulations in order to evaluate the center finding algorithms. These methods were then verified with observational data. In this poster, we present the results of our tests and suggest a new algorithm for centering targets in the slit image of a spectrograph.

Author(s): Hye-In Lee[2], Soojong Pak[2], Jae-Joon Lee[1], Gregory N. Mace[3], Daniel Thomas Jaffe[3]
Institution(s): *1. Korea Astronomy & Space Science institute, 2. Kyung Hee University, 3. The University of Texas*

117.22 – A New Concept of Coronagraph using Axicon Lenses

High-contrast direct imaging of faint objects nearby bright stellar is essential to investigate planetary systems. The goal of such effort is to find and characterize planets similar to Earth that is a challenging task due to it requires a high angular resolution and high dynamic range detections concurrently. A coronagraph that can be suppressed the bright stellar light or active galactic nuclei during the direct detection of astrophysical activities became one of the essential instruments to image exoplanets. In this presentation, a novel concept of a coronagraph using axicon-lenses is will be presented that is conjunction with a method of noninterferometric quantitative phase imaging for direct imaging of exoplanets. The essential scheme of the axicon-lenses coronagraph is the apodization carried out by excluding evaginated images of the planetary systems by a pair of axicon lens. The laboratory based coronagraph imaging is carried out with the axicon-lenses coronagraph setup which included the axicon lenses optics and phase contrast imaging unit. A simulated stellar and its companion are provided by illuminating light through small holes drilled on a thin metal plate. Those diffracted light at the edge of the holes bears a similarity to the light from the bright stellar. The images are evaginated about the optical axis by passing the first axicon lens. Then the evaginated beams of its external area have cut off by an iris which means the suppressed its central light of the bright stellar light preferentially. A symbolic calculation also is carried out to verify the scheme of the the axicon-lenses coronagraph using the symbolic computation program. The simulation results are shown that the the axicon-lenses coronagraph has feature of ability to achieve the IWA smaller than l/D. The laboratory based coronagraph imaging and simulation results support its potentials in direct imaging for finding exo-planet and various astrophysical activities.

Author(s): Jae Ho Choi[1]
Institution(s): *1. Dankook University*

117.23 – The Green Bank Telescope: First Full Winter of Operation at 3mm

The winter of 2016-2017 marks the first season for the Green Bank Telescope (GBT) with full instrumentation in the 3mm band. ARGUS, a 16-pixel array, provides spectroscopic capabilities over 80-116 GHz. MUSTANG-2, a 223 pixel bolometer array, provides extremely sensitive continuum mapping capabilities over a 30 GHz band centered on 90 GHz at an angular resolution of 9”. In addition, there is a 2-pixel receiver that covers the lower part of the 3mm band, 67-93 GHz, for spectroscopy, continuum measurements, and VLBI.

In March, under good night-time conditions, the GBT angular resolution at 109 GHz was measured to be 6.5”. This corresponds to 1.16 lambda/Diameter, exactly as expected from theoretical considerations and identical to the wavelength/Diameter ratio measured at much lower frequencies. Near sidelobe levels are below -20 dB.

This poster will review some results that highlight the GBT's new capabilities in the 3mm band, including new insights into the origin of the anomalous microwave emission, 13CO measurements of a cloud in the Milky Way halo that is in the process making the transition between atomic and molecular gas, HCO+ measurements of infall in a star-forming region, and measurements of dust emission and its spectrum in Orion.

The Green Bank Observatory is a facility of the National Science Foundation, operated under a cooperative agreement by Associated Universities, Inc.

Author(s): Felix J. Lockman[1]
Institution(s): *1. Green Bank Observatory*

117.24 – Long-term Stability of the WFC3 Post-Flash LED Lamp

We report the results of a study of the long-term stability of the LED lamp used in post-flashing WFC3/UVIS images (Martlin, C and Baggett, S., 2017). Having analyzed 644 sub-array exposures taken over the course of just over 3 years we find no significant long-term trends in the LED lamp brightness. The average percentage change per year over all FLASH level and shutter combinations is found to be 0.15% per year with an uncertainty of +/- 0.24% per year. The maximum measured percentage change per year was 0.39% for the highest FLASH level of 20 e- on shutter A which would indicate a change of less than 1 e-/pixel over the roughly 3 years since post-flashing began.

There are, however, occasional short-term deviations in the LED output. The average minimum and maximum outliers over all FLASH level and shutter combination subsets are 4.1% below and 3.5% above, respectively, the mean of that subset. The maximum outlier over all the sets is 5.8% above the normalized mean value, for FLASH level 3/shutter A. The minimum outlier over all sets is also for FLASH level 3/shutter A and is 8.9% below the normalized mean value. Investigation of these outliers has revealed no systematic cause for the excursions and we recommend that users continue using the post-flash as they would have previously.

Author(s): Catherine Martlin[1], Sylvia M. Baggett[1]
Institution(s): *1. STScI*

118 – Extrasolar Planets Poster Session

118.01 – Follow-up Observations of WASP-36

This ongoing work aims to provide follow-up observations of known transiting extrasolar planets using the 35-cm robotic telescope at The University of British Columbia's Southern Observatory (USO), located at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. The observations are part of a long-term effort to search for changes in transit signatures, such as transit timing variations (TTVs) and transit duration variations (TDVs), which could indicate, for example, the presence of additional planets. To help characterize the USO for transit searches, we acquired I-band observations of WASP-36 spanning from 17 January 2017 to 27 February 2017. Three complete transits and one partial transit are included in the data. We present the analysis of these new observations and discuss potential future targets.

Author(s): Taylor Kutra[1], Aaron Boley[2], Anna Hughes [2], Paul Hickson[2]
Institution(s): *1. Quest University Canada, 2. University of British Columbia*

118.02 – Two Years of Hunting Exoplanets at Florida Gulf Coast University

Honors Program participants at Florida Gulf Coast University must complete two of four required "Honors Experiences". One student option is a research experience, and we have developed a "Planet Hunters" course to provide an astronomical research track. In the course, students spend the first semester learning astronomical background and exoplanet detection techniques, while the second semester is devoted to planet searches in Kepler and K2 data, using student-oriented software tools developed specifically for the task. During the first year, students detected both a brown dwarf candidate and a hot Jupiter candidate. In this poster, we review the tools, data sets, and results obtained by students participating in the second year of the course, along with lessons learned for future implementation, including possible extension to TESS data.

Author(s): Derek L. Buzasi[1], Lindsey Carboneau[1], Stephen Childs[1], Tristan Colon[1], Emily Dumouchel[1], William Glenn[1], Morgan Humphrey[1], Alana Hunter[1], Derek Klunk[1], Riley Myers[1], Jacob Nadreau[1], Rebecca Nance[1], Zachary Reynolds[1], Olivia Romas[1], Alexandra Smith[1], Alexis Stansfield[1], Kendyll Sumler[1], Gabrielle Vignet-Williams[1]
Institution(s): *1. Florida Gulf Coast University*

118.03 – Kernel-Phase Interferometry for Super-Resolution Detection of Faint Companions

Direct detection of close in companions (exoplanets or binary systems) is notoriously difficult. While coronagraphs and point spread function (PSF) subtraction can be used to reduce contrast and dig out signals of companions under the PSF, there are still significant limitations in separation and contrast near λ/D. Non-redundant aperture masking (NRM) interferometry can be used to detect companions well inside the PSF of a diffraction limited image, though

the mask discards ~ 95% of the light gathered by the telescope and thus the technique is severely flux limited. Kernel-phase analysis applies interferometric techniques similar to NRM to a diffraction limited image utilizing the full aperture. Instead of non-redundant closure-phases, kernel-phases are constructed from a grid of points on the full aperture, simulating a redundant interferometer. I have developed a new, easy to use, faint companion detection pipeline which analyzes kernel-phases utilizing Bayesian model comparison. I demonstrate this pipeline on archival images from HST/NICMOS, searching for new companions in order to constrain binary formation models at separations inaccessible to previous techniques. Using this method, it is possible to detect a companion well within the classical λ/D Rayleigh diffraction limit using a fraction of the telescope time as NRM. Since the James Webb Space Telescope (JWST) will be able to perform NRM observations, further development and characterization of kernel-phase analysis will allow efficient use of highly competitive JWST telescope time. As no mask is needed, this technique can easily be applied to archival data and even target acquisition images (e.g. from JWST), making the detection of close in companions cheap and simple as no additional observations are needed.
Author(s): Samuel M. Factor[1], Adam L. Kraus[1]
Institution(s): *1. The University of Texas at Austin*

118.04 – The Ruinous Influence of Close Binary Companions on Planetary Systems

The majority of solar-type stars are found in binary systems, and the dynamical influence of binary companions is expected to profoundly influence planetary systems. However, the difficulty of identifying planets in binary systems has left the magnitude of this effect uncertain; despite numerous theoretical hurdles to their formation and survival, at least some binary systems clearly host planets. We present high-resolution imaging of nearly 500 Kepler Objects of Interest (KOIs) obtained using adaptive-optics imaging and nonredundant aperture-mask interferometry on the Keck II telescope. We super-resolve some binary systems to projected separations of under 5 AU, showing that planets might form in these dynamically active environments. However, the full distribution of projected separations for our planet-host sample more broadly reveals a deep paucity of binary companions at solar-system scales. When the binary population is parametrized with a semimajor axis cutoff a cut and a suppression factor inside that cutoff S bin, we find with correlated uncertainties that inside $a_{cut} = 47^{+59}/_{-23}$ AU, the planet occurrence rate in binary systems is only $S_{bin} = 0.34^{+0.14}/_{-0.15}$ times that of wider binaries or single stars. Our results demonstrate that a fifth of all solar-type stars in the Milky Way are disallowed from hosting planetary systems due to the influence of a binary companion.

Author(s): Adam L. Kraus[2], Michael Ireland[1], Andrew Mann[2], Daniel Huber[3], Trent J. Dupuy[2]
Institution(s): *1. Australian National University, 2. The University of Texas at Austin, 3. University of Hawaii - IfA*

118.05 – Constraining the allowed orbits of the directly imaged planetary mass companion GSC 6214-210b

GSC 6214-210 is a young (~10 Myr) pre-main sequence star (SpT =M1) in the Upper Scorpius star-forming region which hosts a wide planetary mass companion (PMC) of 15+/-2 Mjup at a separation of ~320 AU (2.2"). PMCs like GSC6214-201b present a challenge to our understanding of how a planetary system forms around a star - most are too far from their star, and too massive, to be accounted for by our current planet formation models, but very small compared to typical stellar binary companions. PMCs might form in situ, but could also form at small radii and be scattered out to their current orbit through dynamical interactions. Scattering would leave its mark in the orbit that it is on today; constraining the possible orbit of GSC 6124-210b that has been imaged over the course of several epochs gives us insight into how it might have gotten to such a wide separation. We present the relative astrometry of GSC 6214-210 and its wide-orbit PMC using the NIRC2 Adaptive Optics camera at Keck telescope in Hawaii spanning a 7 year time-frame. We tracked precise locations of GSC 6214-210b relative to its host star in the plane of the sky using centroid fitting and astrometric calibrations, accounting for detector distortion and Earth rotation during imaging. Our measurements achieved astrometric uncertainties near the NIRC2 systematic limit (~1-2 mas), allowing determination of its tangential orbital velocity. We will discuss allowed orbital parameters, and possible implications of wide PMCs on planet formation.
Author(s): Logan Pearce[1], Adam L. Kraus[1]
Institution(s): *1. University of Texas at Austin*

118.06 – The Demographics and Properties of Wide-Orbit, Planetary-Mass Companions from PSF Fitting of *Spitzer*/IRAC Images

Over the past decade, a growing population of planetary-mass companions (< 20 M_{Jup}; PMCs) orbiting young stars have been discovered. These objects are at wide separations (> 100 AU) from their host stars, challenging existing models of both star and planet formation. It is unclear whether these systems represent the low-mass extreme of stellar binary formation or the high-mass and wide-orbit extreme of planet formation theories, as various proposed formation pathways inadequately explain the physical and orbital aspects of these systems. Even so, determining which scenario best reproduces the observed characteristics of the PMCs will come once a statistically robust sample of directly-imaged PMCs are found and studied.

We are developing an automated pipeline to search for wide-orbit PMCs to young stars in *Spitzer*/IRAC images. A Markov Chain Monte Carlo (MCMC) algorithm is the backbone of our novel point spread function (PSF) subtraction routine that efficiently creates and subtracts χ^2-minimizing instrumental PSFs, simultaneously measuring astrometry and infrared photometry of these systems across the four IRAC channels (3.6 µm, 4.5 µm, 5.8 µm, and 8 µm). In this work, we present the results of a *Spitzer*/IRAC archival imaging study of 11 young, low-mass (0.044-0.88 M⊙; K3.5-M7.5) stars known to have faint, low-mass companions in 3 nearby star-forming regions (Chameleon, Taurus, and Upper Scorpius). We characterize the systems found to have low-mass companions with non-zero [I1] – [I4] colors, potentially signifying the presence of a circum(sub?)stellar disk. Plans for future pipeline improvements and paths forward will also be discussed. Once this computational foundation is optimized, the stage is set to quickly scour the nearby star-forming regions already imaged by *Spitzer*, identify potential candidates for further characterization with ground- or space-based telescopes, and increase the number of widely-separated PMCs known.

Author(s): Raquel Martinez[1], Adam L. Kraus[1]
Institution(s): *1. The University of Texas at Austin*

118.07 – Greatly enhanced exoplanet biosignature from an interferometer addition to a low resolution spectrograph

Due to the physics of molecular vibration the absorption spectral signature of many atmospheric molecules consists of a group of 40 or so approximately periodic lines. The periodic nature is fortuitous for detecting similar atmospheric features in an exoEarth, since it has a similar shape as an interferometer transmission, whose period is inversely proportional to the delay. We show that the addition of a small interferometer of 0.6 cm delay to an existing dispersive spectrograph can greatly enhance (by many orders of magnitude) the detection of atmospheric features, for initially low resolution spectrographs. We simulate the Gemini Planet Imager measuring a telluric spectrum having native resolution of 40 and 70 in the 1.65 micron and 2 micron bands. These low resolutions are insufficient to resolve the fine features of each atmospheric feature group. However, the addition of a 0.6 cm delay outside the spectrograph and in series with it increases the local amplitude of the signal to a level similar to a R=4400 (at 1.65 micron) or R=3900 (at 2 micron) classical spectrograph.

Author(s): David John Erskine[3], Philip Steven Muirhead[1], Andrew M Vanderburg[2], Andrew Szentgyorgyi[2]
Institution(s): *1. Boston Univ., 2. Harvard Univ., 3. LLNL*

118.08 – Zodiacal Exoplanets in Time: Searching for Young Stars in K2

Nearby young, open clusters such as the Hyades, Pleiades, and Praesepe provide an important reference point for the properties of stellar systems in general. In each cluster, all stars are of the same known age. As such, observations of planetary systems around these stars can be used to gain insight into the early stages of planetary system formation. K2, the revived Kepler mission, has provided a vast number of light curves for young stars in the and elsewhere in the K2 field. We aim to compute rotational periods from sunspot patterns for all K2 target stars and use gyrochronometric relationships derived from cluster stars to determine their ages. From there, we will search for planets around young stars outside the clusters with the ultimate goal of shedding light on how planets and planetary systems evolve with time.

Author(s): Nathan Morris[1], Andrew W Mann[1]
Institution(s): *1. University of Texas at Austin*

118.09 – Detecting exoplanets: jointly modeling radial velocity and stellar activity time series

The radial velocity method is one of the most successful techniques for detecting exoplanets, but stellar activity often corrupts the radial velocity signal. This corruption can make it difficult to detect low mass planets and planets orbiting more active stars. A principled approach to recovering planet radial velocity signals in the presence of stellar activity was proposed by Rajpaul et al. (2015) and involves the use of dependent Gaussian processes to jointly model the corrupted radial velocity signal and multiple proxies for stellar activity. We build on this work in two ways: (i) we propose using dimension reduction techniques to construct more informative stellar activity proxies; (ii) we extend the Rajpaul et al. (2015) model to a larger class of models and use a model comparison procedure to select the best model for the particular stellar activity proxies at hand. Our framework enables us to compare the performance of various proxies in terms of the resulting statistical power for planet detection.

Author(s): David Edward Jones[4], David Stenning[4], Eric B. Ford[3], Robert L Wolpert[2], Thomas J. Loredo[1]
Institution(s): *1. Cornell University, 2. Duke University, 3. Penn State University, 4. SAMSI*

118.10 – K2 Citizen Science Discovery of a Four-Planet System in a Chain of 3:2 Resonances

We report on the discovery of a compact system of four transiting super-Earth-sized planets around a moderately bright K-type star (V=12) using data from

Campaign 12 of NASA's K2 mission. Uniquely, the periods of the planets are 3.6d, 5.4d, 8.3d, and 12.8d, forming an unbroken chain of near 3:2 resonances. It is the first discovery made by citizen scientists participating in the Exoplanet Explorers project on the Zooniverse platform, and was discovered with the help of 15,000 volunteers recruited via the "Stargazing Live" show on Australia's ABC TV channel. K2's open data policy, combined with the unique format of a BBC TV production that does not shy away from including advanced scientific content, enabled the process of a genuine scientific discovery to be executed and witnessed live on air by nearly a million viewers.

Author(s): Geert Barentsen[3], Jessie Christiansen[4], Ian Crossfield[7], Thomas Barclay[5], Chris Lintott[8], Brian Cox[1], Julia Zemiro[2], Brooke Simmons[6], Grant Miller[8]
Institution(s): *1. University of Manchester, 2. ABC, 3. NASA Ames, 4. NASA Exoplanet Science Institute, 5. NASA Goddard, 6. University of California, 7. University of California, 8. University of Oxford*
Contributing team(s): NASA K2, Zooniverse, BBC, ABC

118.11 – How does stellar irradiation make hot Jupiters puffy?

Hot Jupiters appear to be re-inflated as their host stars evolve and become more luminous, shedding more light on the intriguing correlation between stellar irradiation and the size of hot Jupiters. To account for the phenomenon, one of the well-known models is the thermal-tide scenario proposed by Arras and Socrates. We present a linear analysis of semi-diurnal thermal tides in a hot Jupiter. The Coriolis effect is added to our equation, which generates more wave modes than non-rotating models, such as Rossby, Yanai, and inertial waves. We attempt to investigate where and which mode contributes most of the torque that maintains the planet in an asynchronous state against gravitational tides, leading to re-inflation of a hot Jupiter.

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119 – The Solar System Poster Session

119.01 – Study of the Asteroid 2009 DL46

2009 DL46 was discovered by the Catalina Sky Survey on 2009-February 28. This asteroid has a diameter of about 194 meters (119 to 268 meters) [1], and Brian Warner has obtained a rotation period of at least 10 hours [2]. The asteroid 2009 DL46 flew past Earth on May 24/2016 at a distance of about 6.2 lunar distances (0.0158293668567628 A.U) [3]. The NEOWISE mission had a great likelihood to observing this asteroid in early May. Radiotelescopes of Goldstone and Arecibo had planned to make observations of 2009 DL46. "Using the Goldstone facility, we had planned to make radar observations of 2009 DL46" said Landis, Rob R. (HQ-DG000). This asteroid is on list for possible human mission targets. 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 and data of the asteroid were captured with the following equipment: CGE PRO 1400 CELESTRON (f/11 Schmidt-Cassegrain Telescope) and STL-1001 SBIG camera.. Astrometry was carried out, and we calculated the orbital elements. Summary and conclusions: We obtained the following orbital parameters: eccentricity = 0.30731 +/- 0.00025, semi-major axis = 1.460279 +/- 0.000532 A.U, orbital inclination = 7.9503 +/- 0.0048 deg, longitude of the ascending node = 63.45053 +/- 0.00034 deg, argument of perihelion = 159.8804 +/- 0.0024 deg, mean motion = 0.558535 +/- 0.000305 deg/d, perihelion distance = 1.01151363 +/- 3.39e-6 A.U, aphelion distance = 1.90904 +/- 0.00106 A.U, absolute magnitude = 22.5. The parameters were calculated based on 83 observations. Dates: 2016 May: 18 to 21 with mean residual = 0.29 arcseconds. The asteroid has an orbital period of 1.76 years (644.53 days).

[1]
http://newton.dm.unipi.it/neodys/index.php?pc=1.1.9&n=2009DL46.
[2]
http://echo.jpl.nasa.gov/asteroids/2009DL46/2009DL46_planning.html
[3]
http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=2009%20DL46;orb=1;old=0;cov=0;log=0;cad=1#cad
[4]
http://newton.dm.unipi.it/neodys/index.php?pc=2.1.2&o=H78&ab=7

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119.02 – On the Search for Mid-IR and Pure Rotational H_3^+ Emission in Jupiter's Northern Aurora

The first identification of astronomical spectral emission from the H_3^+ ion was made in Jupiter's southern auroral region in the first overtone band near 2 µm (Drossart et al. 1989; Nature 340, 539). Trafton et al. (1989; ApJ 343, L73) also detected H_3^+ emission from this band near each of Jupiter's auroral poles, but without identifying it. Shortly thereafter, Maillard et al (1990; ApJ 363, L37) detected the fundamental band emission near 4 µm. In order to determine the non-LTE column abundance of H_3^+, which is Jupiter's primary ionospheric coolant, we searched in 2001-2002, initially above 10 µm, for emission lines from the H_3^+ pure rotational and ν_1 -> ν_2 difference band. This was done near the northern auroral "hot spot" at System III longitude 180 deg based on predicted theoretical frequencies. The results were reported by Trafton et al. (2009; Icarus 203, 189). No pure rotational lines were detected but there were marginal detections of two metastable difference band lines. The IR-inactive ν_1 levels are populated in thermal equilibrium so these difference band lines are proxies for the pure rotational lines in establishing the total H_3^+ column. These marginal results are consistent with a vibrational relaxation of the ν_2 level by a factor of ~6, consistent with the non-LTE calculation of Melin et al. (2005; Icarus 178, 97).

We report here results from subsequent observations of Jupiter's H_3^+ hot spot spectrum below 10 µm, where better detectivity was expected from the lower thermal background. However, this was offset by the reduced availability of emission from known hydrocarbons, leading to acquisition and guiding difficulty, which was resolved by offsetting from a Galilean satellite. The observations were made with the TEXES high-resolution mid-IR spectrograph at the IRTF telescope on Oct 1, 6, and 8 of 2012. Of the 18 lines predicted for this wavelength regime, half avoided blending with lines apparent in Jupiter's auroral spectrum or falling in spectral orders not observed. We again found no clear detection for the predicted frequencies, but marginal detections are suggested. We will compare the upper limits found here with the earlier results obtained above 10 µm.

Author(s): Laurence M. Trafton[3], Steve Miller[2], John H. Lacy[3], Thomas K. Greathouse[1]
Institution(s): *1. SWRI, 2. UCL, 3. Univ. of Texas, Austin*

119.03 – Systematic Problems With the Original Eddington Experiment of 1919

The observation that starlight passing near the Sun was bent as predicted by Einstein's General Relativity during the 1919 total solar eclipse was one of the great triumphs and turning points of all science. The headline at the top center of the New Times front page declared "Men of Science More or Less Agog Over Results of Eclipse Observations, Einstein Theory Triumphs". Still, there were substantial problems and uncertainties in the decade after 1919 as researchers sought to verify and duplicate Eddington's results. And there have been persistent whispering rumors and claims that Eddington somehow 'fudged' his data. These rumors are certainly wrong, as proven by modern measures and analysis of the original plates, as well as by detailed examinations of the documented analysis and discussions.

With modern knowledge, we can recognize a variety of imperfections in the analysis of Eddington and Dyson. Most of these (e.g., differential aberration, color-dependent refraction) are too small to affect Eddington's basic claim with ~10% accuracy in the Einstein shift. The biggest systematic error, even in modern times, is a degeneracy between the plate scale and the Einstein shift. With only stars measured at similar distances from the Sun, we cannot distinguish between the case where there is the predicted Einstein shift outwards plus the correct plate scale and the case where there is no Einstein shift plus a very slightly mis-measured plate scale. Plate scales cannot be measured perfectly, and plate scales will change on many time scales, as the observer refocuses and as the changing ambient temperature changes the telescope tube length.

For Eddington's 1919 plates, they used only a handful of stars, measured only in one direction, all at similar distances from the Sun, so they are in the case where the degeneracy can dominate the derived measure for the Einstein shift. Further, their plate scales were taken with plates exposed a continent away, months later, and at greatly different temperatures. So, how could Eddington have gotten what we now know to be the correct measure of the Einstein shift - despite not having solved the degeneracy problem?

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200 – LAD Plenary Talk: The Rosetta Mission to Comet 67P/ Churyumov-Gerasimenko, Bonnie Buratti (JPL)

200.01 – The Rosetta Mission to Comet 67P/ Churyumov-Gerasimenko

As remnant bodies left over from the formation of the Solar System, comets offer clues to the physical conditions and architecture of the protosolar nebula. The Rosetta spacecraft, which included an orbiter and a lander that were built and managed by the European Space Agency with NASA contributing four instruments and scientific expertise, was the first mission to orbit and study a comet through a perihelion passage. The targeted Jupiter-family comet 67P/ Churyumov-Gerasimenko, is seemingly two distinct planetesimals stuck together. The comet has not melted or been processed substantially, except for its outer layers, which consist of reaccreted dust and a crust of heated, devolatized, and annealed refractory materials and organics. The exceptionally low density (0.53 gm/cc) of 67P/ implies it is a rubble pile. The comet also appears to contain a hierarchy of building blocks: smaller spherically shaped meter-sized bodies can be seen in its interior, and even smaller cm-sized pebbles were imaged by the camera as the spacecraft made a soft crash landing on the comet's surface on 30 September 2016. The unexpected discovery of molecular oxygen, nitrogen, and hydrogen imply that 67P/ was formed under cold conditions not exceeding 30K. The discovery of many organic compounds, including the amino acid glycine, lends support to the idea that comets, which originate in the Kuiper Belt and the Oort Cloud, brought the building blocks of life to Earth. More laboratory data on organic compounds would help to identify additional organic compounds on the comet. The differences between cometary and terrestrial D/H ratios suggest that comets are not the primary source of terrestrial water, although data on more comets is needed to confirm this result.

Besides being primordial objects offering a window into the formation of solar systems, comets are astrophysical laboratories, ejecting dust and charged particles into the plasma comprising the solar wind. Several unusual phenomena were observed, such as magnetic cavities surrounding the comet, and oscillations in its magnetic field, which led 67P/ to be nicknamed the "singing comet".
NASA funding acknowledged.
Author(s): Bonnie J. Buratti[1]
Institution(s): *1. NASA Jet Propulsion Laboratory, California Inst. of Technology*

201 – Circumstellar Disks, Black Holes, and Binary Stellar Systems

201.01 – Evidence for the Magnetic Origin of Black Hole Accretion Disk Winds

Black hole accretion disks seem to produce plasma outflows that result in blue-shifted absorption features in their spectra1. The literature of the past decade or so has demonstrated that the X-ray absorption-line properties of these outflows are often diverse. They can range in velocity from non-relativistic (~300 km s^-1) to sub-relativistic (~0.1c) over broad range in ionization of the wind plasma. We report here that semi-analytical, self-similar magneto-hydrodynamic (MHD) wind models that have successfully accounted for the X-ray absorber properties of supermassive black can also be applied to the high-resolution X-ray spectrum of the accreting stellar-mass black holes, in particular to the 2005 outburst of GRO J1655–40. This supports the argument of their MHD origin and is consistent with aligned with earlier observational claims. It further hints at the notion of a universal magnetic structure of the observed winds across the known black hole mass range.
Author(s): Chris R. Shrader[2], Keigo Fukumura[1], Demos Kazanas[2], Francesco Tombesi[2], Ehud Behar[3]
Institution(s): *1. JMU, 2. NASA's GSFC, 3. University of Maryland*

201.02 – Charged black holes and black hole binaries in Multi-messenger Astronomy

The possibility of observing electromagnetic signals from gravitational wave events holds great promise for gravitational wave astronomy. I discuss studies of black holes and black hole binaries in both Einstein-Maxwell and Einstein-Maxwell-Dilaton theories, and their implications for LIGO detections and electromagnetic followups, such as Fermi's report of a coincident followup of GW150914.
Author(s): Steve Liebling[1]
Institution(s): *1. Long Island University*

201.03 – Ultraluminous supersoft X-ray sources

While ultraluminous supersoft X-ray sources (ULSs) bear features for intermediate mass black holes or very massive white dwarfs possibly close to Chandrasekhar mass limit, our recent discovery of processing relativistic baryonic jets from a prototype ULS in M81 demonstrate that they are not IMBHs or WDs, but black holes accreting at super-Eddington rates. This discovery strengthens the recent ideas that ULXs are stellar black holes with supercritical accretion, and provides a vivid manifestation of what happens when a black hole devours too much, that is, it will generate thick disk winds and fire out sub-relativistic baryonic jets along the funnel as predicted by recent numerical simulations.
Author(s): Jifeng Liu[1]
Institution(s): *1. National Astronomical Observatory of China*
Contributing team(s): Bai, Yu; Wang, Song; Justham, Stephen; Lu, You-Jun; Gu, Wei-Min; Liu, Qing-Zhong; di Stefano, Rosanne; Guo, Jin-Cheng; Cabrera-Lavers, Antonio; Álvarez, Pedro; Cao, Yi; Kulkarni, Shri

201.04 – Epsilon Aurigae's dark side: A thermal phase curve investigation of the near-eclipse phases

The epsilon Aurigae disk-eclipsing binary system moves through a primary eclipse that lasts just over two years and occurs every 27.1-years. It comprises of a warm F0Ia-star (around 7750 K) and an opaque, circumstellar disk hiding an internal B-star (with a temperature greater than 15,000 K). We present new infrared observations from Spitzer's Infrared Array Camera (IRAC, at 3.6 and 4.5 microns) and The Aerospace Corporation's Broadband Array Spectrograph System (BASS, a 116-element prism system spectrograph spanning 3 – 14 microns) in order to extract the thermal signature of the disk. Previous findings indicate a variable temperature of the disk, depending on its location within the system's orbit: a 550 +\- 50 K temperature was identified during eclipse phases, while a 1150 +\- 50 K temperature was found near secondary—or anti-eclipse—phases by Hoard et al. (2010) and Hoard et al. (2012). We use the latest observations in combination with previously published IRAC and BASS data to compile a more complete thermal phase curve (TPC) of the disk across nearly one-third of the system's orbit. The TPC indicates heating and cooling effects of the disk, pointing to specific ranges of material properties and disk structure. The observations, process, results, and implications will be presented.
Author(s): Richard L Pearson[1], Robert E. Stencel[6], Steve B. Howell[3], D. W. Hoard[2], Daryl L. Kim[4], Ray W. Russell[4], Michael L. Sitko[5]
Institution(s): *1. Astronomy4Kids, 2. Eureka Scientific Inc., 3. NASA Ames Research Center, 4. The*

Aerospace Corporation, 5. University of Cincinnati, 6. University of Denver

201.05 – Orbitally-Modulated X-rays From Millisecond Pulsar Binaries

A large number of new Black Widow (BW) and Redback (RB) rotation-powered millisecond pulsars have been discovered through radio searches of unidentified *Fermi* sources, increasing the known number of these systems from 4 to 28. We model the high-energy synchrotron emission component from particles accelerated to several TeV in intrabinary shocks in two known BW and RB systems, and its predicted modulation at the binary orbital period. Constructing a geometric model of the shock, we use radio eclipse data in conjunction with optical constraints on the binary inclination angle to constrain the shock stagnation point distance from either the pulsar or companion star. We next model the X-ray synchrotron orbital light curves and compare them to those observed from the PSR B1957+20, where the shock surrounds the companion, and PSR J1023+0038, where the shock surrounds the pulsar, to constrain the bulk Lorentz factor of the wind flow as well as further constrain the inclination angle.

Author(s): Alice Kust Harding[1], Zorawar Wadiasingh[2], Christo Venter[2], Markus Boettcher[2], Matthew G. Baring[3]
Institution(s): *1. NASA's GSFC, 2. North West University, 3. Rice University*

201.06 – A SOFIA / FORCAST Picture of Shock-Induced Dust Formation and Evolution in the Classical Nova V5668 Sgr

Conditions in the ejecta of classical novae are often suitable for the production of copious amounts of dust. Evidence for dust condensation is typically revealed by an inflection in the light curve due to obscuration of the central source by dust that can result in up to 6-8 magnitudes of extinction. The dust condensation timescale is quite brief with the transition from the onset of formation to maximum extinction taking only a few days. In many nova systems, there is evidence for simultaneous production of both carbonaceous and oxygen-rich dust species in the ejecta. Recent theoretical work by Derdzinki et al. (2017 MNRAS, submitted) suggests that the observational evidence for both rapid dust condensation and mixed chemistry can potentially be explained by shocks in the ejecta outflow.

The classical nova V5668 Sgr (Nova Sagittarii 2015 No. 2) was discovered on 2015 March 15.6 UT. Carbon monoxide, typically a harbinger of dust formation in novae, was detected in the system only 12 days later (Banerjee et al. 2015) with dust in evidence shortly thereafter. Here we present spectra of V5668 Sgr obtained with the FORCAST mid-infrared instrument on-board the Stratospheric Observatory For Infrared Astronomy (SOFIA) and the Near-Infrared Camera/Spectrograph (NICS) on the 1.2-m Mt. Abu Infrared Observatory. These data include observations from the very start of dust condensation, from the epoch of maximum extinction, and from two epochs at the late stages of evolution as the ejecta were dispersed. We identify the mixed chemistry dust species in the ejecta, assess the conditions in the ejecta giving rise to the dust, and analyze the abundances in the ejecta to understand the processes of dust formation and evolution in the context of the shock-induced dust formation model.

Author(s): L. Andrew Helton[3], Emilia Calvén[3], Ravi Sankrit[3], Robert D. Gehrz[2], Charles E. Woodward[2], R. Mark Wagner[1]
Institution(s): *1. LBT Observatory, 2. Minnesota Institute for Astrophysics, University of Minnesota - Twin Cities, 3. USRA/SOFIA*

201.07 – Magnetic Field Transport in Accretion Disks

The most plausible theories for launching astrophysical jets rely on strong magnetic fields at the inner parts of some accretion disks. An internal dynamo can in principle generate small scale magnetic fields in situ but generating a large scale field in a disk seems a difficult task in the dynamo theories. In fact, as far as numerous numerical experiments indicate, a dynamo-generated field in general would not be coherent enough over the large length scales of order the disk's radius. Instead, a large scale poloidal field dragged in from the environment, and compressed by the accretion, provides a more promising possibility. The difficulty in the latter picture, however, arises from the reconnection of the radial field component across the mid-plane which annihilates the field faster than it is dragged inward by the accretion. We suggest that a combination of different effects, including magnetic buoyancy and turbulent pumping, is responsible for the vertical transport of the field lines toward the surface of the disk. The radial component of the poloidal field vanishes at the mid-plane, which efficiently impedes reconnection, and grows exponentially toward the surface where it can become much larger than the vertical field component. This allows the poloidal field to be efficiently advected to small radii until the allowed bending angle drops to of order unity, and the field can drive a strong outflow.

Author(s): Amir Jafari[2], Ethan Vishniac[1]
Institution(s): *1. John Hopkins University, 2. The Johns Hopkins University*

201.08 – A possible mechanism to detect super-earth formation in protoplanetary disks

Using combined gas+dust global hydrodynamics and radiative transfer simulations, we calculate the distribution of gas and sub-mm-sized dust in protoplanetary disks with a super-Earth at tens of AU, and examine observational signatures of such systems in resolved observations. We confirm previous results that in a typical disk with a low viscosity ($\alpha\lesssim10^{-4}$), a super-Earth is able to open two gaps at $\sim$scale-height away around its orbit in $\sim$mm-sized dust (St$\sim$0.01), due to differential dust drift in a perturbed gas background. Additional rings and gaps may also be produced under certain conditions. These features, particularly a signature ``double-gap'' feature, can be detected in a Taurus target by ALMA in dust continuum under an angular resolution of $\sim0\arcsec.025$ with two hours of integration. The features are robust --- it can survive in a variety of background disk profiles, withstand modest planetary radial migration ($|r/\dot{r}|\sim$ a few Myr), and last for thousands of orbits. Multiple ring/gap systems observed by ALMA were typically modeled using multiple (Saturn-to-Jupiter sized) planets. Here, we argue that a single super-Earth in a low viscosity disk could produce multiple rings and gaps as well. By examining the prevalence of such features in nearby disks, upcoming high angular resolution ALMA surveys may infer how common super-Earth formation events are at tens of au.

Author(s): Ruobing Dong[3], Eugene Chiang[2], Hui Li[1], Shengtai Li[1]
Institution(s): *1. LANL, 2. UC Berkeley, 3. University of Arizona*

202 – Bridging Laboratory & Astrophysics: Dust & Ices

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the interplay between astrophysics with theoretical and experimental studies into the underlying processes in dust and ices that drive our Universe.

202.01 – Cosmic PAHs: from infrared astronomy to laboratory astrophysics

Astronomers consider polycyclic aromatic hydrocarbons (PAHs) to be the smallest dust particles and they use their infrared emission features, the aromatic infrared bands (AIBs), as a diagnostic of physical conditions in regions of star formation from the small scales of protoplanetary disks to the large scales of galaxies. This topic has to face several obstacles. One is the lack of identification of specific PAH species. Another one is that the AIB features carry not only information on the chemical diversity of species but also on photophysical processes involved in the relaxation of PAHs after having been energized by the absorption of UV photons from stars. In this presentation, I will discuss how we can progress in the analysis of the observed AIB spectrum by addressing both the photophysics of isolated PAHs and the formation and evolution of these molecules in cosmic environments. This is achieved by the combination of astronomical models with detailed investigation of molecular processes. The study of these processes has stimulated the development of dedicated laboratory setups and theoretical simulations at the forefront of molecular physics. I will more specifically present the opening given by ERC Synergy project Nanocosmos and the perspectives with the coming James Webb telescope.

Author(s): Christine Joblin[1]
Institution(s): *1. University Toulouse 3 / CNRS*

202.02 – PAH-Mineral Interactions. A Laboratory Approach to Astrophysical Catalysis

Polycyclic Aromatic Hydrocarbon (PAH) molecules carry the infrared emission features which dominate the spectra of most galactic and extragalactic sources. Our study investigates the chemical evolution, chemical properties, physical properties, thermal stability, and photostability of samples produced from the UV-irradiation of simulated mineral dust grains coated with aromatics and astrobiologically relevant ices, using infrared spectroscopy. We investigate the chemical evolution of aromatic organics via anhydrous (no H_2O ice) and hydrous (H_2O ice) mechanisms. The anhydrous mechanism involves UV-induced catalytic reactions between organics and dense-cloud mineral grains, whereas the hydrous mechanism incorporates H_2O-rich ice mixtures with the minerals and organics. These investigations identify the chemical and physical interactions occurring between the organic species, the dust grains and water-rich ices.

These laboratory simulations also generate observable IR spectroscopic parameters for future astronomical observations with infrared telescopes such as SOFIA and JWST as well as provide empirical parameters for input into astronomical models of the early stages of planetary formation. These studies give us a deeper understanding of the potential catalytic pathways mineral surfaces provide and a deeper understanding of the role of ice-organic compositions in the chemical reaction pathways and how these processes fit into the formation of new planetary systems.

In order to achieve these goals we use the Harrick 'Praying Mantis' Diffuse Reflectance Accessory (DRIFTS), which allows FTIR measurements of dust samples under ambient conditions by measuring the light scattered by the dust sample. We have also incorporated a low -temperature reaction chamber permitting the DRIFTS measurements at low temperatures and high-vacuum. This set-up permits the analysis of the solid particles surfaces revealing the chemical species adsorbed as well as their chemical evolution via the introduction of reactant gases, UV irradiation, temperature change, etc.

Author(s): Gustavo Adolfo Cruz Diaz[1], Andrew Mattioda[1]
Institution(s): *1. NASA Ames Research Center*

202.03 – UV-visible spectroscopy of PAHs and PAHNs in supersonic jet. Astrophysical Implications

Polycyclic Aromatic Hydrocarbon (PAHs) molecules are attracting much attention of the astrophysical and astrochemical communities since they are ubiquitous presence in space and could survive in the harsh interstellar medium (ISM). They are proposed as plausible carriers of the still unassigned diffuse interstellar bands (DIBs) for more than two decades now. The so-called PAH - DIB proposal has been based on the abundance of PAHs in the ISM and their stability against the photo and thermo dissociation. Nitrogen is one of the most abundant elements after hydrogen, helium, and carbon [1]. PANHs exhibit spectral features similar to PAHs and may also contribute to unidentified spectral bands.
To prove PAHs-DIBs hypothesis, laboratory absorption spectra of aromatic under astrophysical relevant conditions are of crucial importance to compare with the observed DIBs spectra. The most challenging task is to reproduce as closely as technically possible, the physical and chemical conditions that are present in space. Interstellar PAHs are expected to be present as free, cold, neutral molecules and/or *charged* species [2]. In our laboratory, comparable conditions are achieved using an excellent platform developed in NASA Ames. Our cosmic simulation chamber (COSmIC) allow the measurements of gas phase spectra of neutral and ionized interstellar PAHs analogs by associating a molecular beam with an ionizing discharge to generate a cold plasma expansion (~ 100 K) [3]. Our approach to assign PAH as carriers of some DIBs is record the electronic spectra of cold PAHs in gas phase and systematic search for a possible correspondence in astronomical DIBs spectra. We report in this work UV-visible absorption spectra of neutral PAHs and PAHNs using the cavity ring down spectroscopy (CRDS) technique. We discuss the effect of the substitution of C–H bond(s) by a nitrogen atom(s) in spectroscopic features of PAHs and their astrophysical application.

[1] L. Spitzer, 1978, Physical processes in the interstellar medium. New York Wiley-Interscience
[2] F. Salama, E. Bakes, L.J. Allamandola, A.G.G.M. Tielens, Astrophys. J. 458 (1996) 621
[3] L. Biennier, F. Salama, L. J. Allamandola, & J. J. Scherer, (2003) *J. of Chemical Physics*, *118*(17), 7863–7872
Author(s): Bejaoui Salma[1], Farid Salama[1]
Institution(s): *1. NASA Ames Research center*

202.04 – The Helium Golden Ratios: triplet-singlet and G for He-like X-ray Emission

The existence of a mere two electrons manifests a multitude of interesting and diverse phenomena in the atomic structure of He-like ions including separate spin manifolds (singlets and triplets), unusual ordering of angular momentum states, and intercombination (i) and forbidden (f) radiative transitions. This rich behavior extends also to the dynamics involving He-like ions and various perturbers. While electrons have a propensity for exciting resonant (r) dipole-allowed transitions, heavy particles are far less selective. In this presentation, I'll illustrate how these properties play out in ion-neutral charge exchange (CX) processes which result in He-like product ions. The focus will be on the spin-multiplicity of the atomic ions and the quasi-molecular states involved in the interactions, how these affect the CX cross sections, and their impact on the resulting X-ray spectrum. In particular, the G-ratio, the ratio of Kα line intensities (f+i)/r, is very sensitive to the spin-dependent cross sections which in turn is dependent on the neutral target, whether open-shell like H (Nolte et al. 2012, 2017; Wu et al. 2012) or closed-shell like He or H_2 (Cumbee et al. 2017; Mullen et al. 2016, 2017). Preliminary evidence also suggests that multielectron capture processes may influence the G-ratio when multielectron targets are involved.

Cumbee R. S. et al. 2017, ApJ, submitted
Mullen, P. D. et al. 2016, ApJS, 224, 31
Mullen, P. D. et al. 2017, ApJ, submitted
Nolte, J. et al. 2012, JPB, 45, 245202; 2017, to be submitted
Wu, Y. et al. 2012, JPB, 84, 022711

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Institution(s): *1. NASA GSFC, 2. Univ. of Georgia, 3. University of Illinois Urbana-Champagne, 4. University of North Texas*

203 – Preparing for JWST Observations: Insights from First Light and Assembly of Galaxies GTO Programs II

Opportunities to propose Early Release Science (ERS) observations for the James Webb Space Telescope (JWST) are now available. JWST General Observer (GO) program opportunities will be available in just a few months (November 2017). How can you prepare a successful JWST observing program? Here the Guaranteed-Time Observers (GTO) will describe how they turned their science into JWST observing programs, including JWST proposal planning tool use case examples. This session will focus primarily on First Light and Assembly of Galaxies JWST GTO Programs.

203.01 – Rogier Windhorst

203.02 – Preparing for JWST Observations. Insights from First Light and Assembly of Galaxies GTO Programs II: Studying galaxy properties with MIRI Spectroscopy

The MIRI instrument, a result of the collaborative work of a consortium of European and US institutes, is the only Mid-IR science instrument on board of the James Webb Space Telescope. It will achieve unprecedented sensitivity and spatial resolution in the 5-28 microns wavelength range. A significant part of the MIRI GTO time will be dedicated to extragalactic observations, with the aim of covering a broad range of redshifts and giving new insights to galaxy history through time. While some of the programme will use deep MIRI images complemented with NIR observations, in this talk I will focus on the spectroscopic studies of galaxies planned by the MIRI team. At redshifts of about 7-8 we will study the reionization epoch, by observing spectroscopically confirmed targets. The strong emission lines predicted for these galaxies will be measured with the MIRI MRS (an integral field spectrometer).
Moving closer in redshift, MIRI will be able to provide spatially resolved spectroscopy of massive dusty star forming galaxies at redshifts of about 3 or higher. This will give us the opportunity to study obscured AGNs, internal extinction and star formation activity, and gas-kpc scales kinematics. Finally, in the local Universe, we will observe the nuclei of well-known nearby galaxies with the MIRI MRS and the NIRSpec IFU. The spectra will yield new insights into the distribution, physical conditions, and kinematics of the various gas components (ionized, atomic, or molecular) in the immediate vicinity of the nucleus.
In this contribution I will present this overall spectroscopic GTO program, giving insight into the observing strategies we plan to use for optimally implementing our observations.

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Institution(s): *1. ESA, 2. UKATC, 3. Univeristy of Arizona*
Contributing team(s): The MIRI GTO Team

203.03 – The physics of galaxies as seen with a NIRSpec GTO IFS program

Integral-field spectroscopy (IFS) observations of individual high-redshift galaxies with the NIRSpec instrument on-board JWST will enable us to investigate in detail the most important physical processes driving galaxy evolution across the cosmic epoch.
The NIRSpec guaranteed time observer (GTO) team is investing 270 hours of its GTO time allocation to observe a sample of more than 60 high-redshift galaxies of various types (star forming galaxies, AGN hosts…). In this talk, we will present the science goals of this program, the associated samples and discuss its implementation. We will, in particular, highlight lessons learned that could be useful when designing NIRSpec IFS observation programs.

Author(s): Pierre Ferruit[2], Santiago Arribas[1], Roberto Maiolino[3]
Institution(s): *1. CSIC-INTA, 2. ESA/ESTEC, 3. Kavli Institute for cosmology - Univ. of Cambridge*
Contributing team(s): NIRSpec GTO team

203.04 – The CAnadian NIRISS Unbiased Cluster Survey (CANUCS)

CANUCS GTO program is a JWST spectroscopy and imaging survey of five massive galaxy clusters and ten parallel fields using the NIRISS low-resolution grisms, NIRCam imaging and NIRSpec multi-object spectroscopy. The primary goal is to understand the evolution of low mass galaxies across cosmic time. The resolved emission line maps and line ratios for many galaxies, with some at resolution of 100pc via the magnification by gravitational lensing will enable determining the spatial distribution of star formation, dust and metals. Other science goals include the detection and characterization of galaxies within the reionization epoch, using multiply-imaged lensed galaxies to constrain cluster mass distributions and dark matter substructure, and understanding star-formation suppression in the most massive galaxy clusters. In this talk I will describe the science goals of the CANUCS program. The proposed prime and parallel observations will be presented with details of the implementation of the observation strategy using JWST proposal planning tools.

Author(s): Swara Ravindranath[1]
Institution(s): *1. Space Telescope Science Institute*
Contributing team(s): NIRISS GTO Team

204 – Inner Solar Systems: Origins of Hot and Warm Jupiters

Over the past couple decades, thousands of exoplanets have been discovered on orbits interior to 1 AU, from hot Jupiters orbiting close to their host stars to systems of dynamically-packed super-Earths. Despite exquisite observations of individual worlds, statistical analyses of the growing collection of objects, and extensive simulations of their formation and evolution, the origins of inner Solar Systems remain debated. Inner Solar Systems brings together experts from different perspectives to address outstanding questions about the origins of inner solar systems. We focus on questions where there is tension between observations and theory or different models or interpretations. Each panel-based session addresses a single outstanding question and is led by a panel chair who introduces the topic, moderates the discussion among panelists, and engages the audience in identifying the next steps to resolving the question.

204.01 – Formation of Misaligned Hot Jupiters

The secular dynamical evolution of a hierarchical three-body system in which a distant third object orbits around a binary has been studied extensively, demonstrating that the inner orbit can undergo large eccentricity and inclination oscillations. It was shown before that starting with a circular inner orbit, large mutual inclination (40°-140°) can produce long timescale modulations that drive the eccentricity to extremely large values and can flip the orbit. Here, we demonstrate that starting with an almost coplanar configuration, for eccentric inner and outer orbits, the eccentricity of the inner orbit can still be excited to high values, and the orbit can flip by ~180°, rolling over its major axis. The ~180° flip criterion and the flip timescale are described by simple analytic expressions that depend on the initial orbital parameters. With tidal dissipation, this mechanism can produce counter-orbiting hot Jupiters.

Author(s): Gongjie Li[2], Smadar Naoz[3], Bence Kocsis[1], Abraham Loeb[2]
Institution(s): *1. Eötvös Loránd University, 2. Harvard Univ., 3. UCLA*

204.02 – On the two tales of Warm Jupiters

Warm Jupiters often refer to giant planets with intermediate orbit periods between 10-200 days. Their period range corresponds to the so-called "period valley", the observed dip in occupation in-between the hot Jupiters and cold Jupiters. Observational evidences suggest that they are a distinct population from the hot Jupiters and are likely to be formed from at least two different channels themselves. Earlier radial velocity surveys show that at least a fraction of the warm Jupiters have modest to high eccentricities, supporting these planets migrate to their current location through either secular perturbations or planet-planet scatterings. On the other hand, transiting warm Jupiters found in Kepler are likely to have close-by transiting low mass companions interior/exterior to the warm Jupiter orbits. The existence of the companions indicating the system needs to be near coplanar, and near circular, unlike their radial velocity counter parts. In this talk, I will review observational properties to date of the warm Jupiters, as well as recent advances in the theory of the warm Jupiter formation. I will then discuss how new discoveries from TESS can help with understanding the transition between the hot and warm Jupiter population, and distinguish the contribution from different formation channels.

Author(s): Chelsea Huang[1], Yanqin Wu[1]
Institution(s): *1. University of Toronto*

204.03 – Statistics of Long Period Gas Giant Planets in Known Planetary Systems

The presence of a substantial population of volatile-rich planets on orbits interior to 1AU poses a challenge to models of planet formation and migration. There is currently an ongoing debate as to whether these planets could have formed in situ or instead migrated inward from a more distant formation location. While it has generally been assumed that gas giant planets formed out beyond the ice line and migrated inwards, more recent work has suggested that even these relatively massive planets may be able to form in situ. To constrain possible formation and migration scenarios, we searched for massive, long-period gas giant companions in known exoplanet systems by looking for long-term trends in the RV data. In addition to estimating the total occurrence rate of long-period gas giant companions in known exoplanet systems, we found that hot gas giants inside 1 AU are more likely to have an outer companion than cold gas giants. We also found that planets with an outer companion have higher than average eccentricities than their single counterparts, suggesting that dynamical interactions between planets may play an important role in these systems.

Author(s): Marta Bryan[1]
Institution(s): *1. Caltech*

205 – Plenary Talk: Our Future in Space, Christopher Impey (University of Arizona)

205.01 – Our Future in Space

The Space Age is half a century old. Its early successes were driven by a fierce superpower rivalry between the Soviet Union and the United States, which tended to obscure the fact that exploration and risk-taking is built into human DNA. Decades after we last set foot on the Moon, and years after the Space Shuttle was retired, the space activity is finally leaving the doldrums. A vibrant private sector led by SpaceX, Blue Origins, and Virgin Galactic plans to launch supplies cheaply into Earth orbit and give anyone the chance of a sub-orbital joy ride. New materials are being developed that could lead to space elevators and transform the economics of space travel. Fighting gravity will always be difficult but engineers are rethinking rockets and developing new propulsion technologies. Permanent bases on the Moon and Mars are now within reach, and a new Space Race is brewing, with China ascendant. Medical advances might even allow us to reach for the stars. The talk will review the history and landmarks of the international space program, give a snapshot of the current dynamic situation, and plot the trajectory of the future of space travel. The time has come to envision our future off-Earth.

Author(s): Chris David Impey[1]
Institution(s): *1. Univ. of Arizona*

207 – Supernovae

207.01 – Narrowband Hα Imaging of Old Hydrogen-deficient Supernovae

We report results from our long-term observational survey aimed at discovering late-time interaction between the ejecta of hydrogen-deficient Type I supernovae and the hydrogen-rich envelope expelled from the progenitor star several decades to centuries before explosion. The expelled envelope, moving with a velocity of ~10–100 km/s, is expected to be caught up by the fast-moving SN ejecta several years to decades after explosion depending on the history of the mass-loss process acting in the progenitor star prior to explosion. The collision between the SN ejecta and the circumstellar envelope results in net emission in the Balmer-lines, especially in Hα. For the past three years, we have been using the Direct Imaging Auxiliary Functions Instrument (DIAFI) on the 2.7m Harlan J. Smith Telescope at McDonald Observatory to look for signs of late-time Hα emission in older Type Ia/Ibc/IIb SNe having hydrogen-poor ejecta, via narrow-band imaging. Continuum-subtracted Hα emission has been detected for 13 point sources: 9 SN Ibc, 1 SN IIb and 3 SN Ia events. Thirty-eight SN sites were observed on at least two epochs, from which three objects (SN 1985F, SN 2005kl, SN 2012fh) showed significant temporal variation in the strength of their Hα emission in our DIAFI data. This suggests that the variable emission is probably not due to nearby HII regions, and hence is an important additional hint that ejecta-CSM interaction may take place in these systems. Moreover, we successfully detected the late-time Hα emission from the Type Ib SN 2014C, which was recently discovered as a strongly interacting SN in other wavebands.

Author(s): David A. Pooley[2], Jozsef Vinko[1], Jeffrey M. Silverman[4], J. Craig Craig Wheeler[4], Tamas Szalai[3], Phillip MacQueen[4], Howie H. Marion[4], Krisztián Sárneczky[1]
Institution(s): *1. Konkoly Observatory, 2. Trinity University, 3. University of Szeged, 4. University of Texas*

207.02 – HET LRS2 Observations of Halpha in Old Hydrogen-deficient Supernovae

For 3 years, we have been using narrow-band filters with the DIAFI imager on the HJS 2.7 m telescope to search for evidence that hydrogen-deficient supernovae undergo delayed collision with previously ejected circumstellar material and associated excitation of Halpha (see abstract by Pooley et al.). A powerful method to determine whether detected Halpha flux is from an HII region or a supernova is to obtain spectra; broad lines (> 1000 km/s) will be a certain indicator of a supernova. We have observed about 20 events that ranged in age from about 1000 days to nearly 80 years for which we have detected Halpha in the vicinity of the supernova. So far, only SN 2014C showed the broad H that is concrete evidence of ongoing circumstellar interaction. One interesting aspect revealed by the spectra is that we often pick up the two [N II] lines that typically accompany H in H II regions. Our spectra of SN 2008ha did not show these [N II] lines. The absence of the [N II] lines might be a clue to circumstellar interaction in conditions where the shock had slowed to a point where the H is not detectably broadened.

Author(s): J. Craig Craig Wheeler[5], David A. Pooley[3], Jozsef Vinko[1], Tamas Szalai[4], Howie H. Marion[5], David J. Sand[2], Phillip McQueen[5], Jeffrey M. Silverman[5]
Institution(s): *1. Konkoly Observatory, 2. Texas Tech University, 3. Trinity University, 4. U of Szeged, 5. Univ. of Texas*

207.03D – Is Muzzio 10 the ex-companion star of the PSR B1509-58 progenitor?

PSR B1509-58 is one of the youngest, most energetic pulsars with spin-down age of ~1700 years sitting in the supernova remnant (SNR) G320.4-01.2. Just 18.1" north of the pulsar is a V=11.63 runaway O4.5III(fp) star called Muzzio 10 with a similar distance (~5 kpc) as the pulsar. We make a strong case that a supernova blast happened ~1700 years ago created the SNR G320.4-01.2 and RCW 89 expanding shell, the resultant neutron star is zipping away and now seen as PSR B1509-58, while the companion of the exploding star became unbound and flew away from the explosion site at its prior orbital speed and is now seen as Muzzio 10. We proposed to prove whether Muzzio 10 is the ex- companion star by measuring the proper motions of the pulsar (with 20 ksec of ACIS-I on Chandra in 2017 and archival ACIS-I data from 2000 and 2005) and of Muzzio 10 (with 2 orbits of FGS on HST separated by one year), all to see if the positions coincide 1700 years ago. The identification of a confident ex-companion would allow for testing the predictions of the effects of a SN blast on a nearby star, testing the direction of a pulsar kick with respect to its rotational axis, testing the site of the r-process, and testing the spin-down age of pulsars.

Author(s): Zhichao Xue[1], Bradley E. Schaefer[1], Frederick M. Walter[2]
Institution(s): *1. louisiana state university, 2. Stony Brook University*

207.04 – Interpreting IIn Light Curve Properties using a "simple" modeling approach

The diversity of IIn light curves is revealed as a range of peak absolute magnitudes and light curve decay rates. The characteristics of Type IIn SN light curves have been analytically and numerically analyzed by several studies.
The SN models presented here combine the modeling techniques from both Chevalier and Arnett , to reveal how comparable each model is to two well-observed IIn supernova with distinct light-curve properties, SN 2009ip and SN 2011ht. We compare UV and optical modeled light-curves to IIn observations to identify which general initial condition lead to the difference between SN 2009ip and SN 2011ht light-curve properties. Our results indicate the peak of the light curve is primarily determined by the energy of the explosion and the initial shock-temperature, while the light-curve shape primarily depends on the mass of the ejecta and the explosion energy. In general, the diversity between SN 2009ip and SN 2011ht is based on the mass of the outer ejecta, and energy of the explosion.

Author(s): Janie De La Rosa[1]
Institution(s): *1. University of Texas San Antonio*

207.05 – Large Scale Supernova Structure from Pre- and Post-Explosion Convection

We present results of 3D supernova simulations with initial conditions drawn from 3D models of late stage stellar convection. Simulations are performed with the supernova-optimized smooth particle hydrodynamics code SNSPH and postprocessed using a 522 isotope nuclear reaction network. The simulations also have a non-fixed central compact object that is free to accrete momentum from fall back material. It has been established that neutrino-driven convection can produce large asymmetries in the explosion, but the effects caused by convective anisotropies in late burning shells in the progenitor star and time-varying gravitational potential after the explosion are less well explored. We find that convective motions can result in highly asymmetric overturn of deep layers that are not susceptible to large effects from explosion generated Rayleigh-Taylor and Richtmeyer-Meshkov instabilities. Such overturn can produce regions with a strong alpha-rich freezeout and high iron abundances morphologically similar to the iron-rich structure in the southeast quadrant of Cassiopeia A.

Author(s): Patrick A. Young[1], Gregory Vance[1], Carola Ellinger[2], Chris Fryer[2]
Institution(s): *1. Arizona State University, 2. Los Alamos National Laboratory*

208 – Bridging Laboratory & Astrophysics: Molecules

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the interplay between astrophysics with theoretical and experimental studies into the underlying molecular processes that drive our Universe.

208.01 – LAD Dissertation Prize Talk: Molecular Collisional Excitation in Astrophysical Environments

While molecular excitation calculations are vital in determining particle velocity distributions, internal state distributions, abundances, and ionization balance in gaseous environments, both theoretical calculations and experimental data for these processes are lacking. Reliable molecular collisional data with the most abundant species - H_2, H, He, and electrons - are needed to probe material in astrophysical environments such as nebulae, molecular clouds, comets, and planetary atmospheres. However, excitation calculations with the main collider, H_2, are computationally expensive and therefore various approximations are used to obtain unknown rate coefficients. The widely-accepted collider-mass scaling approach is flawed, and alternate scaling techniques based on physical and mathematical principles are presented here. The most up-to-date excitation data are used to model the chemical evolution of primordial species in the Recombination Era and produce accurate non-thermal spectra of the molecules H_2^+, HD, and H_2 in a primordial cloud as it collapses into a first generation star.

Author(s): Kyle M. Walker[1]
Institution(s): *1. LOMC UMR 6294 CNRS - Université du Havre*

208.02 – Organic molecules in protoplanetary disks: new insights and directions with ALMA

The current era of exoplanet detection and characterisation has revealed the ubiquity and diversity of (exo)planetary systems around stars in the solar neighbourhood. Protoplanetary disks around young stars contain the matter - dust, gas, and ice - which will go into forming new (exo)planetary systems. One open question regarding this planet-building material is the degree of chemical complexity inherited and/or attained in the protoplanetary disk prior to planet formation. Is it possible that our chemical origins lie as far back as the molecular cloud from which the sun formed?

The superior sensitivity and resolution of ALMA, the Atacama Large Millimeter/submillimeter Array is allowing us, for the first time, to detect and resolve emission from complex organic molecules (> 5 atoms) in protoplanetary disks around nearby young stars. In this talk, I will review recent exciting detections of chemical complexity in disks with ALMA, and discuss the implications of these observations on our understanding of chemistry (in the gas and solid phase) in the planet- and comet-forming zones. I will also speculate on the potential for ALMA to observe molecules on higher 'rungs' on the 'ladder' of complexity in nearby planet-forming disks, and describe how such detections can provide insight on the importance of interstellar chemistry on our origins.

Author(s): Catherine Walsh[1]
Institution(s): *1. University of Leeds*

208.03 – Computational Investigations of Rovibrational Quenching of HD due to Collisions in the Interstellar Medium

When conducting an examination of distant astronomical objects, scientists rely on measurements derived from astronomical observations of these objects, which are primarily collected using spectroscopy. In order to interpret spectroscopic data collected on astronomical objects, it is necessary to have a background of accurate dynamical information on interstellar molecules at one's disposal. Seeing as most of the observable infrared radiation in the universe is emitted by molecules excited by collisional processes in the interstellar gas, generating accurate data on the rate of molecular collisions is of salient interest to astronomical endeavors.

The collisional system we will be focusing on here is He-HD, an atom-diatom system in which He collides with HD. We are primarily interested in the cooling capabilities of this system, as these species are predicted to have played an important role in the formation of primordial stars, which emerged from a background composed solely of Hydrogen, Helium, and their compounds. HD is being investigated because it has a finite dipole moment and is hence a powerful radiator, and He due to its relative abundance in the early universe. Using a hybrid OpenMP/MPI adaption (vrrm) of a public-domain scattering package, cross sections for He-HD collisions are computed for a swathe of both rotational and vibrational states across a range of relevant kinetic energies, then integrated to produce rate coefficients. Due to the vast computational requirements for performing these operations, the use of high-powered computational resources is necessary.

The work of CV was funded by a UGA Center for Undergraduate Research Opportunities award. We thank the University of Georgia GACRC and NERSC at Lawrence-Berkeley for computational resources and Brendan McLaughlin for assistance.
Author(s): Clark Goodman Veazey[1], Yier Wan[1], Benhui H. Yang[1], P. Stancil[1]
Institution(s): *1. The University of Georiga*

208.04 – High excitation rovibrational molecular analysis in warm environments

Inspired by advances in infrared observation (e.g., Spitzer, *Herschel* and ALMA), we investigate rovibrational emission CO and SiO in warm astrophysical environments. With recent innovation in collisional rate coefficients and rescaling methods, we are able to construct more comprehensive collisional data with high rovibrational states (vibration up to v=5 and rotation up to J=40) and multiple colliders (H_2, H and He). These comprehensive data sets are used in spectral simulations with the radiative transfer codes RADEX and Cloudy. We obtained line ratio diagnostic plots and line spectra for both near- and far-infrared emission lines over a broad range of density and temperature for the case of a uniform medium. Considering the importance of both molecules in probing conditions and activities of UV-irradiated interstellar gas, we model rovibrational emission in photodissociation region (PDR) and AGB star envelopes (such as VY Canis Majoris, IK Tau and IRC +10216) with Cloudy. Rotational diagrams, energy distribution diagrams, and spectra are produced to examine relative state abundances, line emission intensity, and other properties. With these diverse models, we expect to have a better understanding of PDRs and expand our scope in the chemical architecture and evolution of AGB stars and other UV-irradiated regions. The soon to be launched James Webb Space Telescope (JWST) will provide high resolution observations at near- to mid-infrared wavelengths, which opens a new window to study molecular vibrational emission calling for more detailed chemical modeling and comprehensive laboratory astrophysics data on more molecules.

This work was partially supported by NASA grants NNX12AF42G and NNX15AI61G. We thank Benhui Yang, Kyle Walker, Robert Forrey, and N. Balakrishnan for collaborating on the collisional data adopted in the current work.
Author(s): Ziwei Zhang[2], Phillip C. Stancil[2], Renata Cumbee[1], Gary J. Ferland[3]
Institution(s): *1. NASA Goddard, 2. The University of Georgia, 3. University of Kentucky*

209 – Preparing for JWST Observations: Insights from Birth of Stars and Protoplanetary Systems GTO Programs

Opportunities to propose Early Release Science (ERS) observations for the James Webb Space Telescope (JWST) are now available. JWST General Observer (GO) program opportunities will be available in just a few months (November 2017). How can you prepare a successful JWST observing program? Here the Guaranteed-Time Observers (GTO) will describe how they turned their science into JWST observing programs, including JWST proposal planning tool use case examples. This session will focus primarily on Birth of Stars and Protoplanetary Systems JWST GTO Programs.

209.01 – Probing Initial Conditions and Outcomes: Star and Planet Formation Programs within the NIRCam GTO Program

With its extraordinary sensitivity, wavelength coverage from < 1 to 5 microns, 2.2x4.4 arc minute field of view, and diversity of observing modes, NIRCam on JWST offers very powerful capabilities to explore the origins of stars and planets. Here we describe programs planned within the NIRCam GTO Program including: i) extinction mapping of pre-stellar cores; ii) massive star formation; iii) embedded clusters and the end of the IMF; iv) imaging and spectroscopy of young stellar objects; and v) excitation of PAH features. We will describe the scope of each program, selection of observing modes and rationale, as well as provide some explicit examples of program design. We will also review the expected outcomes, illustrating the power of NIRCam to answer questions fundamental to understanding the origins of stars and planets.

Author(s): Michael Meyer[1]
Institution(s): *1. University of Michigan*
Contributing team(s): NIRCam Star and Planet Formation Theme Team

209.02 – Star Formation in the Local Group with NIRSpec

I will present a NIRSpec GTO programme showcasing the multi-object spectroscopy capabilities of NIRSpec for stellar studies. We will obtain medium- and high-resolution spectra of hundreds of known pre-main sequence (PMS) stars with different ages hosted in massive starburst clusters in the Galaxy and Magellanic Clouds. These PMS stars were identified from HST photometry as objects with strong Hα excess emission (EW > 10Å). Each cluster contains about 500–1000 such PMS stars in a typical 3'x3' field, thereby guaranteeing optimal filling of the NIRSpec Micro-Shutter Array. The ultimate scientific goal is to understand the very nature of the mass accretion process, and how the corresponding infall of gas from the circumstellar disc onto the star depends on the mass, age, and metallicity of the PMS object. This study is unique, since spectroscopic studies of PMS objects so far are limited to the solar neighbourhood and no information exists for starburst clusters and for non-solar metallicity.

Author(s): Guido De Marchi[1]
Institution(s): *1. European Space Agency*
Contributing team(s): NIRSpec Guaranteed Time Observation Team

209.03 – JWST/Mid-InfraRed (MIRI) Guaranteed Time Observing programs on Star and Planet Formation

The Mid-InfraRed (MIRI) Guaranteed Time Observing (GTO) programs on star and planet formation cover both nearby low mass star formation regions, distant Galactic massive star formation regions and star formation studies of the Magellanic Clouds. Although the programs focus primarily on MIRI imaging and MIRI medium resolution spectroscopy (MRS), observations with the Near-InfraRed (NIRCam) and the Near-InfraRed Spectrograph (NIRSpec) are also taken for a comprehensive study. The programs pursue objects and regions previously studied with Spitzer, Herschel, HST and ALMA. The Galactic studies will reveal greater detail both spatially and spectroscopically of the star and planet formation processes. The observations of star formation in the Magellanic Clouds will reveal details at ~0.1 pc. Details of the observation planning will be shown for two MIRI GTO programs that focus on the study of star formation at low metallicity: one star formation region in the Small Magellanic Cloud and one star formation region in the Large Magellanic Cloud.

Author(s): Margaret Meixner[2], Bram Ochsendorf[1], Olivia Jones[2], Omnarayani Nayak[1]
Institution(s): *1. Johns Hopkins University, 2. STScI*
Contributing team(s): MIRI Team

209.04 – Using NIRISS to study the formation and evolution of stars, disks, and planets

NIRISS on JWST is a powerful instrument for the study of star, disk, and planet formation and evolution. In this talk I will highlight the Wide Field Slitless Spectroscopy (WFSS) and Aperture Masking Interferometry (AMI) modes of NIRISS, along with lessons learned determining optimal observing strategies and project implementation in APT. The NIRISS WFSS mode uses a grism to provide modest resolution (R ~ 150) spectra of all sources within the observed field of view. Cold low-mass objects are distinct at NIRISS wavelengths (1.5 and 2.0 microns, in this case), and can be characterized through their speactra by their temperature and surface gravity sensitive molecular absorption features. Thus, WFSS observations will be an efficient way to locate and enumerate the young brown dwarfs and rogue planets in nearby star-forming regions. Alternatively, the NIRISS AMI mode offers the highest spatial resolution available on JWST at wavelengths greater than 2.5 micron, 70 - 400 mas, and modest inner working angle contrast, dm ~ 10, for individual bright sources. A significant advantage of observing from space is that, along with the phase closure, the interferometric phase amplitudes can also be recovered allowing some reconstruction of extended emission. Observations with AMI will be made of candidate and postulated planets forming within transition disks around young stars and for somewhat older planets in known extra-solar planetary systems. The AMI mode will also be used to study the zodiacal light in a bright debris disk system and to search for binary companions of Y dwarfs.

Author(s): Doug I. Johnstone[1]
Institution(s): *1. Herzberg Inst. of Astrophysics*
Contributing team(s): JWST NIRISS GTO Team

210 – Inner Solar Systems: Connecting Inner Solar Systems to Outer Solar Systems

Over the past couple decades, thousands of exoplanets have been discovered on orbits interior to 1 AU, from hot Jupiters orbiting close to their host stars to systems of dynamically-packed super-Earths. Despite exquisite observations of individual worlds, statistical analyses of the growing collection of objects, and extensive simulations of their formation and evolution, the origins of inner Solar Systems remain debated. Inner Solar Systems brings together experts from different perspectives to address outstanding questions about the origins of inner solar systems. We focus on questions where there is tension between observations and theory or different models or interpretations. Each panel-based session addresses a single outstanding question and is led by a panel chair who introduces the topic, moderates the discussion among panelists, and engages the audience in identifying the next steps to resolving the question.

210.01 – Circumstellar Material on and off the Main Sequence

There is evidence of circumstellar material around main sequence, giant, and white dwarf stars that originates from the small-body population of planetary systems. These bodies tell us something about the chemistry and evolution of protoplanetary disks and the planetary systems they form. What happens to this material as its host star evolves off the main sequence, and how does that inform our understanding of the typical chemistry of rocky bodies in planetary systems? In this talk, I will discuss the composition(s) of circumstellar material on and off the main sequence to begin to answer the question, "Is Earth normal?" In particular, I look at three types of debris disks to understand the typical chemistry of planetary systems—young debris disks, debris disks around giant stars, and dust around white dwarfs. I will review the current understanding on how to infer dust composition for each class of disk, and present new work on constraining dust composition from infrared excesses around main sequence and giant stars. Finally, dusty and polluted white dwarfs hold a unique key to our understanding of the composition of rocky bodies around other stars. In particular, I will discuss WD1145+017, which has a transiting, disintegrating planetesimal. I will review what we know about this system through high speed photometry and spectroscopy and present new work on understanding the complex interplay of physics that creates white dwarf pollution from the disintegration of rocky bodies.

Author(s): Amy Steele[2], John H. Debes[1], Drake Deming[2]
Institution(s): *1. STScI, 2. University of Maryland*

210.02 – Observsational Planet Formation

Planets form in gaseous protoplanetary disks surrounding newborn stars. As such, the most direct way to learn how they form from observations, is to directly watch them forming in disks. In the past, this was very difficult due to a lack of observational capabilities; as such, planet formation was largely a subject of pure theoretical astrophysics. Now, thanks to a fleet of new instruments with unprecedented resolving power that have come online recently, we have just started to unveil features in resolve images of protoplanetary disks, such as gaps and spiral arms, that are most likely associated with embedded (unseen) planets. By comparing observations with theoretical models of planet-disk interactions, the masses and orbits of these still forming planets may be constrained. Such planets may help us to directly test various planet formation models. This marks the onset of a new field — observational planet formation. I will introduce the current status of this field.

Author(s): Ruobing Dong[2], Zhaohuan Zhu[3], Jeffrey Fung[1]
Institution(s): *1. UC Berkeley, 2. University of Arizona, 3. UNLV*

210.03 – The Smallest Signatures of Other Worlds

As a litany of worlds gently tug on the stars around us, we are driven to build instruments that can discern the smallest stellar motions and reveal this population of planets. However, the path to extreme precision spectroscopy, required to detect Earth-like planets, is a difficult one that must be forged from technological and scientific discovery. Anchored by the success of HARPS and other precision spectrographs in the field, we are moving into the development of complete radial velocity systems that are capable of detecting small signatures in both the optical and near-infrared. I will discuss two such instruments being developed at Penn State: (a) the Habitable Zone Planet Finder, a NIR spectrograph for the 10m Hobby-Eberly Telescope, and (b) NEID, an extreme precision optical instrument which is the cornerstone of the NN-EXPLORE partnership. The science enabled by these instruments will be far-reaching, ranging from immediate follow-up of close-in TESS and K2 candidates, to identifying potentially well-separated targets for future space missions such as WFIRST-AFTA, HabEx or LUVOIR, and providing new insight into the hitherto unexplored connections between populaces of inner and outer solar systems.

Author(s): Arpita Roy[1]
Institution(s): *1. The Pennsylvania State University*

211 – Plenary Talk: Planet Nine from Outer Space, Konstantin Batygin (Caltech)

211.01 – Planet Nine from Outer Space

At the outskirts of the solar system, beyond the orbit of Neptune, lies an expansive field of icy debris known as the Kuiper belt. The orbits of the individual asteroid-like bodies within the Kuiper belt trace out highly elongated elliptical paths, and require hundreds to thousands of years to complete a single revolution around the Sun. Although the majority of the Kuiper belt's dynamical structure can be understood within the framework of the known eight-planet solar system, bodies with orbital periods longer than about 4,000 years exhibit a peculiar orbital alignment that eludes explanation. What sculpts this alignment and how is it preserved? In this talk, I will argue that the observed clustering of Kuiper belt orbits can be maintained by a distant, eccentric, Neptune-like planet, whose orbit lies in approximately the same plane as those of the distant Kuiper belt objects, but is anti-aligned with respect to those of the small bodies. In addition to accounting for the observed grouping of orbits, the existence of such a planet naturally explains other, seemingly unrelated dynamical features of the solar system.

Author(s): Konstantin Batygin[1]
Institution(s): *1. California Institute of Technology*

212 – Plenary Talk: Flows and Flares Around the Nearest Supermassive Black Hole -- Sgr A*, Daniel Wang (University of Massachusetts)

212.01 – Flows and Flares Around the Nearest Supermasive Black Hole --- Sgr A*

Sgr A* is an asymptotic example of low-luminosity accretion onto a supermassive black hole (SMBH). The proximity of Sgr A* allows for a unique close-up view of this common accretion phenomenon in the Universe. I will review recent X-ray studies of Sgr A*, ranging from a statistical analysis of daily flares to a multi-demensional modeling of the quiescent accretion state. These studies have provided new insights into the physical processes associated with the inflow, outflow, and radiation in regions from the immediate vicinity of the SMBH out to its Bondi radius. I will also discuss how future studies can further the understanding of the phenomenon.

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213 – Laboratory Astrophysics Division Poster Session

213.01 – Kinetic and radiation-hydrodynamic modeling of x-ray heating in laboratory photoionized plasmas

In experiments performed at the Z facility of Sandia National Laboratories a cm-scale cell filled with neon gas was driven by the burst of broadband x-rays emitted at the collapse of a wire-array z-pinch turning the gas into a photoionized plasma. Transmission spectroscopy of a narrowband portion of the x-ray flux was used to diagnose the plasma. The data show a highly-ionized neon plasma with a rich line absorption spectrum that permits the extraction of the ionization distribution among Be-, Li-, He- and H-like ions. Analysis of the spectra produced atomic ground and low excited state areal densities in these ions, and from the ratio of first-excited to ground state populations in Li-like neon a temperature of 19±4eV was extracted to characterize the x-ray heating of the plasma. To interpret this observation, we have performed data-constrained view-factor calculations of the spectral distribution of the x-ray drive, self-consistent modeling of electron and atomic kinetics, and radiation-hydrodynamic simulations. For the conditions of the experiment, the electron distribution thermalizes quickly, has a negligible high-energy tail, and is very well approximated by a single Maxwellian distribution. Radiation-hydrodynamic simulations with either LTE or NLTE (i.e. non-equilibrium) atomic physics provide a more complete modeling of the experiment. We found that in order to compute electron temperatures consistent with observation inline non-equilibrium collisional-radiative neon atomic kinetics needs to be taken into account. We discuss the details of LTE and NLTE simulations, and the impact of atomic physics on the radiation heating and cooling rates that determine the plasma temperature. This work was sponsored in part by DOE Office of Science Grant DE-SC0014451, and the Z Facility Fundamental Science Program of SNL.

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213.02 – New Data for Modeling Hypersonic Entry into Earth's Atmosphere: Electron-impact Ionization of Atomic Nitrogen

Meteors passing through Earth's atmosphere and space vehicles returning to Earth from beyond orbit enter the atmosphere at hypersonic velocities (greater than Mach 5). The resulting shock front generates a high temperature reactive plasma around the meteor or vehicle (with temperatures greater than 10,000 K). This intense heat is transferred to the entering object by radiative and convective processes. Modeling the processes a meteor undergoes as it passes through the atmosphere and designing vehicles to withstand these conditions requires an accurate understanding of the underlying non-equilibrium high temperature chemistry. Nitrogen chemistry is particularly important given the abundance of nitrogen in Earth's atmosphere. Line emission by atomic nitrogen is a major source of radiative heating during atomspheric entry. Our ability to accurately calculate this heating is hindered by uncertainties in the electron-impact ionization (EII) rate coefficient for atomic nitrogen.

Here we present new EII calculations for atomic nitrogen. The atom is treated as a 69 level system, incorporating Rydberg values up to n=20. Level-specific cross sections are from published B-Spline R-Matrix-with-Pseudostates results for the first three levels and binary-encounter Bethe (BEB) calculations that we have carried out for the remaining 59 levels. These cross section data have been convolved into level-specific rate coefficients and fit with the commonly-used Arrhenius-Kooij formula for ease of use in hypersonic chemical models. The rate coefficient data can be readily scaled by the relevant atomic nitrogen partition function which varies in time and space around the meteor or reentry vehicle. Providing data up to n=20 also enables modelers to account for the density-dependent lowering of the continuum.

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213.04 – The contribution of double electron capture processes to charge exchange with multielectron targets

Previous investigations into charge exchange and its applications to X-ray spectroscopy have tended to focus almost exclusively on single electron capture processes. Mounting evidence suggests that ignoring the contribution of double electron capture will yield inaccurate results. Accordingly, charge exchange cross sections for single and double electron capture are calculated using multichannel Landau-Zener theory for the system Ne^{10+} +He. (n,l,n′,l′)-resolved double electron cross sections are generated then used in conjunction with branching ratios to determine cross sections for double capture with and without autoionization. These cross sections are used to generate X-ray spectra for each of the processes. Results indicate that the inclusion of double electron capture events is essential if one is to properly describe the spectral shape resulting from charge exchange and the subsequent radiative stabilization

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213.05 – Lifetimes and Oscillator Strengths for Ultraviolet Transitions Involving *ns*²*nd* ²*D* and *nsnp*² ²*D* terms in Pb II, Sn II, and Ge II

Radiative transitions of heavy elements are of great importance in astrophysics. Studying the transition rates and their corresponding oscillator strengths allows us to determine abundances of these heavy elements and therefore leads to better understanding of neutron capture processes. We provide the results of our studies on the transitions involving $ns^2nd\ ^2D$ and $nsnp^2\ ^2D$ terms to the ground term for Pb II, Sn II, and Ge II. These transitions are also of interest due to their strong mixing. Our studies involve experimental measurements performed at the Toledo Heavy Ion Accelerator and theoretical multi-configuration Dirac Hartree-Fock (MCDHF)[1] calculations using the development version of the GRASP2K package[2]. The results are compared with Pb II lines seen in spectra acquired with the *Hubble Space Telescope* and with other values available in the literature.

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[2] P. Jönsson et al., Comput. Phys. Commun. 184, 2197 (2013).

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213.06 – Charge transfer in collisions of O+8 with H and He atoms

The discovery of highly charged ions in the solar wind, and their interaction with interstellar and planetary atoms, has renewed interest in accurate charge exchange data in the astrophysics community. A time-dependent lattice method is used to calculate charge transfer cross sections in O+8 collisions with H and He atoms. O+8 (nl) capture cross sections are obtained for 1s to 6h subshells at an incident energy of 8.18 keV/amu.

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213.07 – The Contribution of Charge Exchange to the X-ray Spectrum of M82

As the resolution of space-based X-ray detectors improve, deducing the mechanism(s) responsible for the observed emission has in many cases proved to be problematic. Emission from most galactic and extragalactic sources are typically attributed to hot thermal plasmas driven by electron impact excitation (EIE). Other sources may be due to radiative recombination (RR) from a photoionized plasma. Charge exchange (CX) is another process that has more recently been ascribed to observed emission, particularly when unexplained by EIE or RR. However, laboratory astrophysics data on CX needed to accurately model X-ray emission has not generally been available. As a consequence a number of approximate CX models have been developed to ascertain the relative importance of CX (e.g., the AtomDB Charge eXchange model, ACX, Smith et al. 2012). Recently, Zhang et al. (2014) combined ACX with a thermal plasma model to study the X-ray emission from starburst galaxy M82, obtained with the XMM-Newton/reflection grating spectrometer (RGS). They deduced that for some emission lines the CX contribution could be a much as 87%. Here we revisit their M82 model,
but replace ACX with explicitly computed and benchmarked CX cross sections from the Kronos database (Cumbee et al. 2017, Mullen et al. 2017).

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Mullen, P. D. et al. 2017, ApJ, submitted
Smith, R. K. et al. 2012, AN, 333, 301
Zhang, S. et al. 2014, ApJ, 794, 61
This work was partially supported by NASA grants NNX09AC46G and NNG09WF24I.

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213.08 – Advances in Interstellar and Planetary Laboratory Astrophysics with Ames' COSmIC Facility

The COSmIC facility was developed at NASA Ames to study interstellar, circumstellar and planetary analogs in the laboratory [1]. COSmIC stands for "Cosmic Simulation Chamber" and is dedicated to the study of neutral and ionized molecules 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 forming, processing and monitoring simulated space conditions in the laboratory. It is composed of a Pulsed Discharge Nozzle (PDN) expansion that generates a plasma in a free supersonic jet expansion coupled to high-sensitivity, complementary in situ diagnostics 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 [2].
Recent advances achieved in laboratory astrophysics using COSmIC will be presented, in particular the advances that have been achieved in the domain of the diffuse interstellar bands (DIBs) [3] and in monitoring, in the laboratory, the formation of dust grains and aerosols from their gas-phase molecular precursors in environments as varied as circumstellar outflows [4] and planetary atmospheres [5, 6]. 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 of the on-going studies for astronomy.

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[6] Sciamma-O'Brien E., Upton K. and Salama F. Icarus, in press (2017)

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213.09 – Collisional Quenching of Highly-Excited H_2 due to H_2 Collisions

Collision-induced energy transfer involving H_2 molecules are of significant interest, since H_2 is the most abundant molecular species in the universe. Collisional de-excitation rate coefficients of the H_2-H_2 system are necessary to produce accurate models of astrophysical environments. However, accurate calculations of collisional energy transfer are still a challenging problem, especially for highly-excited H_2 because a large number of levels must be included in the calculation.

Currently, most data are limited to initial rotational levels j up to 8 or initial vibrational levels up to 3. The vast majority of these results involve some form of a reduced-dimensional approach which may be of questionable accuracy. A reliable and accurate four-dimensional PES computed by Patkowski et al. is used in this work along with two quantum scattering programs (MOLSCAT and vrrmm). Another accurate full-dimensional PES has been reported for the H_2-H_2 system by Hinde.

Not all transitions will be explicitly calculated. A zero-energy scaling technique (ZEST) is used to estimate some intermediate transitions from calculated rate coefficients. New inelastic quenching cross section for para-H_2+para-H_2 collisions with initial level j= 10, 12, 14, 18, 24 are calculated. Calculations for other de-excitation transitions from higher initial levels and collisions involving other spin isomer of hydrogen, ortho-H_2+para-H_2, ortho-H_2+ortho-H_2 and para-H_2+ortho-H_2 are in progress. The coupled- states approximation is also applied to obtain cross sections at high energy.

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Contributing team(s): This work was partially support by Hubble grant HST-AT-13899. We thank Kyle Walker for assistance with vrrmm.

213.10 – A Heuristic Model of Primordial Chemical Evolution in the Reionization Era

We develop a model of the evolution of the chemical composition of the early Universe under the influence of Population III (Pop III) stars. Solving rate equations for primordial atomic and molecular species subject to the Cosmic Background Radiation (CBR), we predict the fractional abundances of these species as a function of redshift (z). The CBR, however, eventually becomes negligible after the first stars become active. To extend the recombination era model (Gay et al. 2011), we simulate the formation of many stars from a cloud of a given mass, constrained by the Initial Mass Function (IMF), and assign to each star a mass appropriate lifetime, effective temperature, and radius (Schaerer 2002). We randomly distribute the stars across a parcel of gas with the number being controlled by the star formation rate as a function of z (Hartwig et al. 2015). Runs of our chemistry code are then spawned for each star in parallel once a star turns on. We model the propagation of the radiation front as it expands and ionizes the surrounding region, until the star has lived its lifetime. Taking the average of the data sets produce by the collection of stars in the region, we are able to obtain a prediction of the evolution of the chemical composition of the entire modeled region from the Recombination era into the Reionization era.

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213.11 – Experimental and Ab-Initio Studies of High Temperature Reactions in Vapor above Sio_2/Al_2O_3 and SiO_2/CaO Melts

The study of solid-liquid equilibrium is well established for alloys likely to be found on hot, rocky extra-solar planets. However, in atmospheres established above these magmas, molecules released from the components of the melt can react to form adducts; new molecules containing fragments of these precursors. These adducts are not predicted from equilibrium modeling codes unless their thermodynamic properties are input prior to simulation. In addition, the spectroscopic properties and vapor pressures relative to their melt conditions may be poorly known. Using a Knudsen cell heated in a custom e-beam evaporator, the binary systems of SiO_2/Al_2O_3 and SiO_2/CaO were synthesized at temperatures above 2000 K. The molecules evaporated from the melts were deposited into an Argon matrix held at 15 K and studied using mass spectrometry and FTIR. The results were then compared to molecular stability calculations derived from ab-initio molecular dynamics simulations using VASP©, and to IR spectra obtained using Gaussian©. Based on this analysis, a set of molecular adducts was found for each of the two alloy systems. The thermodynamic properties of each adduct were then simulated and used as input parameters for equilibrium calculations of vapor pressures as a function of temperature. The applications of these results to exoplanet observations is also discussed.
This work was supported by NASA EPSCoR (Experimental Program to Stimulate Competitive Research). NNX13AE52A , "Understanding the Atmospheres of Hot Earths and the Impact on Solar System Formation"with NASA Glenn Research Center, Missouri State University and Washington University, St. Louis
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213.12 – Laboratory Measurements for Deuterated Astrochemistry

Deuterated molecules are powerful probes of the cold interstellar medium (ISM). Observations of D-bearing molecules are used to infer the chemistry of the ISM and to trace out physical conditions such as density, ionization fraction, and thermal history. The chemistry of the cold ISM results from a complicated interplay between gas-phase processes, reactions on dust grain surfaces, and chemistry occurring both in and on the icy mantles of dust grains. Our focus here is on an improved understanding of the relevant deuterated gas-phase chemistry. At the low temperatures and densities typical of the cold ISM, much of this chemistry is driven by binary ion-neutral reactions, which are typically barrierless and exoergic (as compared to neutral-neutral reactions which often have significant activation energies).
One of the biggest challenges in generating a reliable deuterated gas-phase astrochemical network is the uncertainty of the necessary rate coefficients. The vast majority of available chemical kinetic data are for fully hydrogenated species. For those D-bearing reactions where no laboratory data are available, two approaches have been adopted for converting the fully hydrogenated data into partial- and fully-deuterated species. The first approach simply "clones" the H-bearing reactions into D-bearing reactions and assumes that the rate coefficients are the same. The second approach uses a simple mass scaling relationship based on the Langevin formalism.
We have initiated a series of laboratory measurements aimed at resolving this issue. For this we use our novel dual-source, merged fast-beams apparatus, which enables us to study reactions of neutral atoms and charged molecules. Using co-propagating beams enables us to achieve collision energies corresponding to temperatures as low as 25 K, limited only by the divergences of the two beams. Recently we have measured the reaction $C + H_2^+(D_2^+)$ forming $CH^+(CD^+) + H(D)$. We are now studying $D + H_3^+(D_2H^+)$ forming $H_2D^+(D_3^+) + H$. Here we report on these results and discuss their astrochemical implications.
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213.13 – Laser interferometry of radiation driven gas jets

In a series of experiments performed at the 1MA Zebra pulsed power accelerator of the Nevada Terawatt Facility nitrogen gas jets were driven with the broadband x-ray flux produced during the collapse of a wire-array z-pinch implosion. The wire arrays were comprised of 4 and 8, 10μm-thick gold wires and 17μm-thick nickel wires, 2cm and 3cm tall, and 0.3cm in diameter. They radiated 12kJ to 16kJ of x-ray energy, most of it in soft x-ray photons of less than 1keV of energy, in a time interval of 30ns. This x-ray flux was used to drive a nitrogen gas jet located at 0.8cm from the axis of the z-pinch radiation source and produced with a supersonic nozzle. The x-ray flux ionizes the nitrogen gas thus turning it into a photoionized plasma. We used laser interferometry to probe the ionization of the plasma. To this end, a Mach-Zehnder interferometer at the wavelength of 266 nm was set up to extract the atom number density profile of the gas jet just before the Zebra shot, and air-wedge interferometers at 266 and 532 nm were used to determine the electron number density of the plasma right during the Zebra shot. The ratio of electron to atom number densities gives the distribution of average ionization state of the plasma. A python code was developed to perform the image data processing, extract phase shift spatial maps, and obtain the atom and electron number densities via Abel inversion. Preliminary results from the experiment are promising and do show that a plasma has been created in the gas jet driven by the x-ray flux, thus demonstrating the feasibility of a new experimental platform to study photoionized plasmas in the laboratory. These plasmas are found in astrophysical scenarios including x-ray binaries, active galactic nuclei, and the accretion disks surrounding black holes[1]. This work was sponsored in part by DOE Office of Science Grant DE-SC0014451.

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213.14 – Understanding Solar Coronal Heating through Atomic and Plasma Physics Experiments

Recent solar observations suggest that the Sun's corona is heated by Alfven waves that dissipate at unexpectedly low heights in the corona. These observations raise a number of questions. Among them are the problems of accurately quantifying the energy flux of the waves and that of describing the physical mechanism that leads to the wave damping. We are performing laboratory experiments to address both of these issues.

The energy flux depends on the electron density, which can be measured spectroscopically. However, spectroscopic density diagnostics have large uncertainties, because they depend sensitively on atomic collisional excitation, de-excitation, and radiative transition rates for multiple atomic levels. Essentially all of these data come from theory and have not been experimentally validated. We are conducting laboratory experiments using the electron beam ion trap (EBIT) at Lawrence Livermore National Laboratory that will provide accurate empirical calibrations for spectroscopic density diagnostics and which will also help to guide theoretical calculations.

The observed rapid wave dissipation is likely due to inhomogeneities in the plasma that drive flows and currents at small length scales where energy can be more efficiently dissipated. This may take place through gradients in the Alfven speed along the magnetic field, which causes wave reflection and generates turbulence. Alternatively, gradients in the Alfven speed across the field can lead to dissipation through phase-mixing. Using the Large Plasma Device (LAPD) at the University of California Los Angeles, we are studying both of these dissipation mechanisms in the laboratory in order to understand their potential roles in coronal heating.

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213.15 – Experimental design to understand the interaction of stellar radiation with molecular clouds

Enhanced star formation triggered by local O and B type stars is an astrophysical problem of interest. O and B type stars are massive, hot stars that emit an enormous amount of radiation. This radiation acts to either compress or blow apart clumps of gas in the interstellar media. For example, in the optically thick limit, when the x-ray radiation in the gas clump has a short mean free path length the x-ray radiation is absorbed near the clump edge and compresses the clump. In the optically thin limit, when the mean free path is long, the radiation is absorbed throughout acting to heat the clump. This heating explodes the gas clump. Careful selection of parameters, such as foam density or source temperature, allow the experimental platform to access different hydrodynamic regimes. The stellar radiation source is mimicked by a laser irradiated thin gold foil. This will provide a source of thermal x-rays (around ~100 eV). The gas clump is mimicked by a low-density foam around 0.150 g/cc. Simulations were done using radiation hydrodynamics codes to tune the experimental parameters. The experiment will be carried out at the Omega laser facility on OMEGA 60.

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213.16 – Laboratory unravelling of matter accretion in young low-mass stars

Accretion dynamics in the forming of young stars is still widely investigated because of limitations in observations and modelling. In our present understanding, matter from the accretion disk (10^{11}-10^{13} cm^{-3} / 2000 K) is connected to the star by the extended magnetosphere (0.1 –1 kG) and falls down into the stellar surface at the free fall velocity (500 km.s^{-1}). At the impact, a shock is forming, leading to observable X-ray and UV emissions, the amount of each channel being still incompatible with the present shock dynamic modelling at the impact region. Through scaled laboratory experiments of collimated plasma accretion onto a solid in the presence of a magnetic field, we open the first experimental window on this phenomenon by tracking, with spatial and temporal resolution, the dynamics of the system and simultaneously measuring multiband emissions. This is performed using a laser-created thermal plasma embedded in an external 20T pulsed magnetic field. As a result of the magnetized plasma expansion, a collimated jet is formed, having an aspect ratio >10, a temperature of tens of eV, an electron density of 1.5.10^{18} cm^{-3} and propagating at 750 km.s^{-1}. This jet, acting as the accretion column following the magnetic field lines then impacts a solid obstacle located on its path, mimicking the stellar surface. This setup differs by many ways from previous experiments using unmagnetized shock-tube configurations having unwanted edge-constraints.

We observe in our experiment that matter, upon impact, is laterally ejected from the solid surface, then refocused by the magnetic field toward the incoming stream. Such ejected matter forms a plasma shell that envelops the shocked core, reducing escaped X-ray emission. Discussed in the light of 3D-MHD simulations in the laboratory conditions as well as 2D-MHD astrophysical-scaled simulations, these experimental results shed light on one possible structure reconciling current discrepancies between mass accretion rates derived from X-ray and optical observations.

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213.17 – Experiment to measure oxygen opacity at high density and temperature

In recent years, there has been a debate over the abundances of heavy elements (Z > 2) in the solar interior. Recent solar atmosphere models [Asplund 2009] find a significantly lower abundance for C, N, and O compared to models used roughly a decade ago. This discrepancy has led to an investigation of opacities through laboratory experiments and improved opacity models for many of the larger contributors to the sun's opacity, including iron and oxygen. Recent opacity measurements of iron disagree with opacity model predictions [Bailey et al, 2015]. Although these results are still controversial, repeated scrutiny of the experiment and data has not produced a conclusive reason for the discrepancy. New models have been implemented in the ATOMIC opacity code for C, O and Fe to address the solar abundance issue [Colgan, 2013]. Armstrong et al [2014] have also implemented changes in the ATOMIC code for low-Z elements. However, no data currently exists to test the low-Z material models in the regime relevant to the solar convection zone. We present an experimental design using the opacity platform developed at the National Ignition Facility to study the oxygen opacity at densities and temperatures near the solar convection zone conditions.

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213.18 – Atomic kinetics of a neon photoionized plasma experiment at Z

We discuss an experimental effort to study the atomic kinetics in neon 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 various distances 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 from about 3 to 80 erg*cm/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 collecting both time-integrated and time-gated spectra is used to collect absorption spectra. A suite of IDL programs has been developed to process the experimental data to produce transmission 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 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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213.19 – Laboratory polarized phase curve measurement of airless body analog materials

When Sun light is incident on surfaces of airless bodies the reflected radiation is often found to be more polarized in the direction perpendicular to the scattering plane than in the parallel direction at small phase angle. This so-called negative polarization effect may be quantitatively characterized by several parameters of the polarized phase curve (PPC) such as the minimum degree of polarization (DOP) (Pmin), the inversion angle where the DOP changes its sign (alpha_inv), and the slope of the PPC near alpha_inv (h). Currently these parameters are believed to be complementary to spectroscopic data in revealing asteroid surface compositions and physical properties. Because of the paucities of laboratory experiments on analog materials, there are many open questions in interpretations of observational data. For example, earlier studies show that bare rocks, fine dust and rubble piles are located in different regions in the parameter space spanned by Pmin and alpha_inv, while recent observational results tend to support the idea that the locations are more related to surface mineralogy and chemical compositions; the compositions of F asteroids and the Barbarians with smallest and largest inversion angles. How much information on space weathering can polarization provide? To answer these questions, we have set up a three wavelength light scattering system to measure analog materials with different physical properties. The system can measure the Mueller matrices of packed surfaces from 2 to 135 deg. phase angle. We present measurement results on typical pure minerals with refractive indices varying from 1.4 to 2.4, both in bulk and grains, to understand the effects of refractive index on Pmin, alpha_inv and h. Olivine and pyroxene grains and their mixtures, both original and irradiated by a 1064 nm pulse laser at different energy levels in a vacuum chamber, are used to simulate asteroid surface materials with varying degrees of space weathering. Their reflectance spectra and polarization phase curves are used to understand to what degree spectroscopic and polarization data can be complementary.

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213.20 – Atomic Data for UV Astronomy

Spectral lines of iron-group elements are observed in a wide variety of astrophysical objects including A- and B- type stars, the interstellar medium, quasi-stellar objects, and absorption spectra from quasi-stellar objects. Although lines of Fe II, Cr II and Ni II often dominate these spectra, even relatively low abundance elements such as Sc II can be important as their abundance can be significantly higher in some objects. In order to understand these spectra it is necessary to obtain and analyze high-resolution, high signal-to-noise ratio laboratory spectra to obtain accurate wavelengths and energy levels for all of the singly-ionized elements from scandium through nickel.

For many years, the atomic spectroscopy groups at the National Institute of Standards and Technology (NIST), USA and Imperial College London, UK, have been recording high-resolution spectra of iron-group elements using Fourier transform (FT) and grating spectroscopy in order to complete their analyses. This has resulted comprehensive analyses of Fe II and Cr II from below 100 nm to 5000 nm, covering almost all of the region in which allowed lines of these spectra are typically observed in astronomical objects. Analysis of spectra of V II, Ti II and Co II recorded in less comprehensive regions using FT spectroscopy have also been published. I shall present our current work to extend the observations and analysis of Co II and Ti II to shorter wavelengths, and our comprehensive analyses of Mn II, Ni II, and Sc II.

Author(s): Gillian Nave[1]
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214 – Galaxies Poster Session

214.03 – HST Imaging of the (Almost) Dark ALFALFA Source AGC 229385

We present deep HST imaging photometry of the extreme galaxy AGC 229385. This system was first discovered as an HI source in the ALFALFA all-sky HI survey. It was cataloged as an (almost) dark galaxy because it did not exhibit any obvious optical counterpart in the available wide-field survey data (e.g., SDSS). Deep optical imaging with the WIYN 3.5-m telescope revealed an ultra-low surface brightness stellar component located at the center of the HI detection. With a peak central surface brightness of 26.4 mag/sq. arcsec in g and very blue colors (g-r = -0.1), the stellar component to this gas-rich system is quite enigmatic. We have used our HST images to produce a deep CMD of the resolved stellar population present in AGC 229385. We clearly detect a red-giant branch and use it to infer a distance of 5.50 ± 0.23 Mpc. The CMD is dominated by older stars, contrary to expectations given the blue optical colors obtained from our ground-based photometry. Our new distance is substantially lower than earlier estimates, and shows that AGC 229385 is an extreme dwarf galaxy with one of the highest M_{HI}/L ratios known.

Author(s): Samantha Brunker[4], John Joseph Salzer[4], Kristen B. McQuinn[6], Steven Janowiecki[3], Luke Leisman[2], Katherine L. Rhode[4], Elizabeth A. Adams[1], John M. Cannon[5], Riccardo Giovanelli[2], Martha P. Haynes[2]

Institution(s): *1. ASTRON, 2. Cornell University, 3. ICRAR, University of Western Australia, 4. Indiana University, 5. Macalester College, 6. University of Texas at Austin*

214.05 – Radio continuum JVLA observations of the dwarf galaxy Sextans A

We present 20-cm Jansky Very Large Array (JVLA) observations of the star-forming dwarf galaxy Sextans A. Located at the outer edge of the Local Group, with an oxygen abundance of less than one-tenth of the Solar abundance (12+log O/H = 7.49), Sextans A provides a nearby laboratory for the study of low-metallicity star formation processes. This galaxy is a weak source in the infrared, but exhibits evidence for vigorous star formation-powered outflows in ionized gas, including large-scale H-alpha shells and filaments up to a kpc in length. Sextans A has not previously been detected in radio continuum. The upgraded JVLA and WIDAR correlator provide enhanced sensitivity over previous studies. We resolve a 3.0 mJy (+/- 0.3 mJy) continuum source centered on the brightest star formation region in Sextans A. Using two relatively interference-free windows at 1.4 GHz and 1.85 GHz, we are able to measure the spectral slope of the detected emission. We estimate the non-thermal contribution and the strength of the galaxy's magnetic field. We discuss the impact of low metallicity on the reliability of the IR/radio relation.

Author(s): Jacqueline A. Monkiewicz[1], Devon Powell[3], Ralf-Juergen Dettmar[2], Dominik Bomans[2], Judd D. Bowman[1], Evan Scannapieco[1]
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214.06 – Tidal Tales of Minor Mergers: Star Formation in the Tidal Tails of Minor Mergers

While major mergers and their tidal debris are well studied, equal mass galaxy mergers are relatively rare compared to minor mergers (mass ratio <0.3). Minor mergers are less energetic than major mergers, but more common in the observable universe, and thus likely played a pivotal role in the formation of most large galaxies. Tidal debris regions have large amounts of neutral gas but a lower gas density and may have higher turbulence. We use star formation tracers such as young star cluster populations and H-alpha and CII emission to determine the different factors that may influence star formation in tidal debris. These tracers were compared to the reservoirs of molecular and neutral gas available for star formation to estimate the star formation efficiency (SFE). The SFR in tidal debris can reach up to 50% of the total star formation in the system. The SFE of tidal tails in minor mergers can range over orders of magnitude on both local and global scales, and include several star forming regions with higher than normal SFE. From the tidal debris environments in our study, this variance appears to stem from the formation conditions of the debris. Current surveys of the 2.12 micron line of molecular hydrogen, CO(1-0), and HI for 15 minor mergers, are providing a larger sample of environments to study the threshold for star formation that can inform star formation models, particularly at low densities.

Author(s): Karen A. Knierman[1], Jacqueline A. Monkiewicz[1], Paul A. Scowen[1], Christopher E. Groppi[1]
Institution(s): *1. School of Earth and Space Exploration - Arizona State University*

214.07 – The Tully-Fisher relationship for isolated early-type galaxies

Extremely isolated early-type galaxies (IEGs), which are virtually free of galaxy harassment that is typical in galaxy clusters and groups, offer insight into the evolution of the broader class of early-type galaxies (ETGs). Here, we present analysis of single-dish atomic hydrogen (HI) line profiles for twelve IEGs observed with the Green Bank Telescope (GBT). These IEGs are separated in comoving distance by at least 2.5 Mpc from galaxies brighter than M_V =-16.5. We present a Tully-Fisher diagram for our IEG sample using measured HI line profile velocity widths. The derived Tully-Fisher relationship and HI line profile properties of the isolated sample are compared to those of ETGs from the literature.

Author(s): Trisha L. Ashley[1], Pamela M. Marcum[1], Michael N. Fanelli[1]
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214.08 – Dissecting the assembly and star formation history of disks and bulges in nearby spirals using the VENGA IFU survey

Integral field spectroscopy of nearby galaxies provides a powerful and unparalleled tool for studying how galaxies assemble the different components -- the bulge, bar, and disk-- that define the Hubble sequence. We explore the assembly and star formation history of these components using galaxies in the VIRUS-P Exploration of Nearby Galaxies (VENGA) survey of 30 nearby spiral galaxies. Compared to other integral field spectroscopy studies of spirals, our study benefits from high spatial sampling and resolution (typically a few 100 pc), large coverage from the bulge to the outer disk, broad wavelength range (3600-6800 A), and medium spectral resolution (120 km/s at 5000 A). In this poster, we present the methodology and data illustrating the exquisite, high-quality, spatially-resolved spectra out to large radii, and the distribution, kinematics, and metallicity of stars and ionized gas. We discuss the next steps in deriving the star formation history (SFH) of bulge, bar, and disk components, and elucidating their assembly pathway by comparing their SFH and structural properties to theoretical models of galaxy evolution. This project is supported by the NSF grants AST-1614798 and AST-1413652.

Author(s): Andreia Jessica Carrillo[3], Shardha Jogee[3], Kyle Kaplan[3], Tim Weinzirl[2], Guillermo A. Blanc[1]
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214.09 – The Milky Way's Mass Inferered by Satellite Kinematics from the Illustris Simulation

A precise interpretion of the Milky Way's dark matter halo mass has limited our ability to depict the Milky Way in cosmological context. One of the noteworthy issues is that only a handful of tracers — satellite galaxies — probe the gravitational potential at large radii, and converting observed velocities into a constraint on the mass profile requires significant assumptions. High resolution cosmological simulations provide a powerful tool for interpreting data, but most results to date rely on dark-matter-only simulations that neglect the effects of galaxy formation physics. We compare the orbital kinematics of satellite galaxies in the Illustris simulation with its dark-matter-only counterpart, which allows us to compare, on an object-by-object basis, the differences influenced in orbits from baryonic physics. We quantify the effects of galaxy formation physics on orbital distributions of satellites and describe how these differences affect inferences for the mass of the Milky Way.

Author(s): Alexander Lazar[1], Michael Boylan-Kolchin[1]
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214.10 – Mapping the Extent of M82's outlfows with VIRUS-P

Starburst-driven outflows (SBDOs) and other feedback processes play a critical role in the evolution of galaxies through the regulation and disruption of star formation. However, our ability to observe and quantify feedback from SBDOs directly has been limited by the inability to obtain the spectroscopy needed for physical diagnostics over the large areas of local SBDOs. We present integral field spectroscopy taken with the George and Cynthia Mitchell Spectrograph (VIRUS-P) on the 2.7 meter Harlan J. Smith Telescope at McDonald Observatory mapping the full extent of M82's northern outflow out to ~12kpc covering ~139 square arcminutes. We measured line ratios ([OIII]/Hβ, [OI]/Hα, [NII]/Hα), [SII]/Hα) for each spaxel in our fields. Using Ionization Diagnostic Diagrams (IDDs) we spatially map shock dominated regions which we show trace the biconical structure of the outflow. M82 is a local galaxy (z~0.000677) and the classical example of a starburst galaxy with vigorous outflows. As a result it has been comprehensively studied for nearly 50 years. However, we present the most sensitive and extensive map of the warm ionized gas to date from the disk to the Hα cap at ~12kpc.

Author(s): Briana Indahl[2], Gary J. Hill[2], Niv Drory[1], Emily McLinden[2]
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215 – Molecular Clouds and Dust Poster Session

215.01 – Highly Excited Molecular Hydogren in Shocked Molecular Gas: Line Emission from Newly Reformed H_2?

We report high sensitivity *K*-band spectra of the Herbig-Haro 7 bow shock and selected portions of the energetic outflow in the Orion Molecular Cloud, each a location of bright line emission by shocked molecular hydrogen (H_2). Among the many detected emission lines of H_2 are some from highly excited ro-vibrational levels, with upper state energies as high as the dissociation limit near 50,000 K, much higher than previously observed. In all cases the H_2 level populations are well fit by a two-temperature model with the vast majority of the H_2 at a temperature near 2,000 K but with one to a few percent of the H_2 at a temperature near 5,000 K. The existence of the latter H_2 appears to be broadly consistent with it having recently reformed following collisional dissociation by the shock; however, the well-defined kinetic temperature of 5,000 K is surprising. The presence of such high temperature H_2 appears to be a common characteristic of shock-excited molecular gas.

Author(s): Thomas R. Geballe[3], Michael G. Burton[2], Rosemary E. Pike[1]
Institution(s): *1. Academia Sinica, 2. Armagh Observatory, 3. Gemini Obs.*

215.02 – H2, CO, and dust absorption through cold molecular clouds

We have made observations with IGRINS on the Harlan J. Smith telescope at McDonald Observatory of near-infrared absorption by H2, CO, and dust toward stars behind molecular clouds, primarily the TMC. Prior to these observations, the abundance of H2 in molecular clouds, relative to the commonly used tracer CO, had only been measured toward a few embedded stars, which may be surrounded by atypical gas. The new observations provide a representative sample of these molecules in cold molecular gas. We find N(H2)/Av ~ 0.9e+21, N(CO)/Av ~ 1.6e+17, and H2/CO ~ 6000. The measured H2/CO ratio is consistent with that measured toward embedded stars in various molecular clouds, but half that derived from mm-wave observations of CO emission and star counts or other determinations of Av.

Author(s): John H. Lacy[1], Chris Sneden[1], Hwihyun Kim[1], Daniel Thomas Jaffe[1]
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215.03 – A Comparative Study of H_2 Excitation and Physical Conditions in Interstellar and Circumstellar Photo-dissociation Regions

"Photo-dissociation" or "Photon-dominated" Regions (PDRs) exist in the ISM at the interfaces between photo-ionized and molecular gas, where UV radiation sets the ionization state, chemistry, and excitation at the edge of the molecular zone. In these regions, excited rotational-vibrational ("rovibrational") states of the ground electronic state of H_2 are fluorescently populated when the absorption of far-UV photons conveys the molecules into excited electronic states from which they rapidly decay. Downward transitions from the excited rovibrational states produce a rich spectrum of near-infrared emission lines. Since these quadrupole lines are generally optically thin, their fluxes scale with the populations of the upper levels of the respective transitions, providing excellent probes of the excitation and physical conditions in the emitting regions. We present and compare high resolution (R~45,000) near-infrared (1.45-2.45 μm) spectra, obtained on the 2.7 m Harlan J. Smith Telescope at McDonald Observatory with the Immersion Grating INfrared Spectrometer (IGRINS) (Park et al. 2014, SPIE, 9147, 1), for a variety of Galactic PDRs including regions of high mass star formation, reflection nebulae, and planetary nebulae. Typically a large number of transitions, up to about 100 individual lines, are seen in each source. We fit grids of Cloudy models (Ferland et al. 2013, RMxAA, 49, 137) to the observed H_2emission to constrain physical parameters such as the temperature, density, and UV field of each PDR and explore the similarities and differences between the various environments where PDRs arise.

This work used the Immersion Grating INfrared Spectrometer (IGRINS), developed under a collaboration between the University of Texas at Austin and the Korea Astronomy and Space Science Institute (KASI) with the financial support of the US National Science Foundation (NSF grant AST-1229522) to the University of Texas at Austin, and the Korean GMT Project of KASI. We also acknowledge support from the NSF grant AST-0708245 and JPL RSA 1427884.

Author(s): Kyle Kaplan[1], Harriet L. Dinerstein[1], Daniel Thomas Jaffe[1]
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215.04 – Gas Temperature Demography and the HI-to-H_2 Transition in the Magellanic Clouds

Given their proximity and low metallicity, the Magellanic Clouds provide the ideal laboratory to study the evolution of gas in the interstellar medium. We present first results from a new HI and OH absorption line study using the ATCA to measure the warm-to-cold atomic fraction and the atomic-to-molecular transition in the Large and Small Magellanic Clouds (LMC and SMC, respectively). The survey targets 48 sources in the LMC and 29 sources in the SMC, which covers more sources at higher senstitivity and spectral resolutin than previous absorption line measurement studies. We decompose the emission and absorption spectra using the autonomous gaussian decomposition software GaussPy (Lindner et al. 2015), which allows us to measure the spin temperature and optical depth of the HI gas. These measurements of the optical depth allow us to constrain the amount of "CO-faint" gas that is optically thick HI gas. Initial analysis indicates that we measure higher spin temperatures than the previous studies (Dickey et al. 1994, Marx-Zimmer et al. 2000), and cold atomic gas fractions of ~20%. We currently have no detections of OH absorption and an upper limit on the column density of molecular gas in the targeted lines of sight of ~few x 10^{22}cm^{-2}, which is consistent with the dust-based molecular gas estimates.

Author(s): Katherine Jameson[1], Naomi McClure-Griffiths[1], Boyang Liu[8], Lister Staveley-Smith[3], John Miller Dickey[7], Alberto D. Bolatto[6], Joanne Dawson[2], Helga Dénes[1], Di Li[4], Snezana Stanimirovic[9], Mark G. Wolfire[6], Tony H. Wong[5]
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215.05 – Kinematic Study of Ionized and Molecular Gases in Ultracompact HII Region in Monoceros R2

Monoceros R2 (Mon R2) is an UltraCompact HII region (UCHII) surrounded by several PhotoDissociation Regions (PDRs). It is an excellent example to investigate the chemistry and physics of early stage of massive star formation due to its proximity (830pc) and brightness. Previous studies suggest that the wind from the star holds the ionized gas up against the dense molecular core and the higher pressure at the head drives the ionized gas along the shell. In order for the model to work, there should be evidence for dense molecular gas along the shell walls, irradiated by the UCHII region and perhaps entrained into the flow along the walls.
We obtained the Immersion Grating INfrared Spectrograph (IGRINS) spectra of Mon R2 to study the kinematic patterns in the areas where ionized and molecular gases interact. The position-velocity maps from the high resolution (R~45,000) H- and K-band (1.4-2.5μm) IGRINS spectra demonstrate that the ionized gases (Brackett and Pfund series, He and Fe emission lines; $\Delta v \approx$ 40km/s) flow along the walls of the surrounding clouds. This is consistent with the model by Zhu et al. (2008). In the PV maps of the H2 emission lines there is no obvious motion ($\Delta v \approx$ 10km/s) of the molecular hydrogen right at the ionization boundary. This implies that the molecular

gas is not taking part in the flow as the ionized gas is moving along the cavity walls.

This work used the Immersion Grating Infrared Spectrograph (IGRINS) that was developed under a collaboration between the University of Texas at Austin and the Korea Astronomy and Space Science Institute (KASI) with the financial support of the US National Science Foundation (NSF; grant AST-1229522), of the University of Texas at Austin, and of the Korean GMTProject of KASI.
Author(s): Hwihyun Kim[1], John H. Lacy[2], Daniel Thomas Jaffe[2]
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215.06 – Multi-wavelength Study of Diffuse Atomic and Molecular Gas

Diffuse atomic and molecular gas is revealed through a combination of absorption lines against background targets and emission. We describe a project that combines results on ultraviolet (UV) and visible absorption with those obtained from the *Herschel* key program GOTC+ (Galactic Observations of Terahertz C^+) to develop a comprehensive picture of neutral diffuse gas in the Galaxy. [C II], H I, and CO emission acquired for the GOTC+ survey reveal the presence of warm neutral atomic gas, cold neutral atomic gas, CO-dark H_2 gas (molecular gas not seen in CO emission), and denser molecular gas in different kinematic components. We derive the component structure (number of clouds and their column densities) seen in absorption at visible wavelengths from Ca II, Ca I, K I, CH, CH^+, and CN and compare that to the emission from [C II], H I, and CO and its isotopologues. Absorption lines from additional atoms (including C I, O I, and Ni II) and molecules (CO) from UV spectra obtained with the *Hubble Space Telescope* are used to expand the kinematic correspondences. Preliminary results on physical conditions (gas temperature and density) inferred from analyses of CN chemistry and excitation of neutral and singly-ionized carbon, neutral oxygen, and CO are also presented.
Author(s): Steven Robert Federman[5], Johnathan Rice[5], Nicolas Flagey[1], Adam M. Ritchey[6], Daniel E. Welty[3], Paul Goldsmith[2], William Langer[2], Jorge L. Pineda[2], David L. Lambert[4], Jean-Louis Lemaire[7]
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215.07 – Design of Laboratory Experiments to Study Photoionization Fronts

Here we present the theoretical foundation for a laboratory experiment to study photoionization fronts. Photoionization fronts play important roles in the formation and evolution of structure in the Universe. A properly designed experiment will have to control the recombination rate, electron impact ionization rate, and the initial thermal spectrum. We show that such an experiment can be designed, but requires the use of the largest high-energy-density laser facilities, such as Omega, Z, and NIF. We also show that prior experiments do not actually generate photoionization fronts, rather a heat front is produced by heat conductions. We show some initial simulation results of the current experimental design and characterize the ionization front.
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Institution(s): *1. University of Michigan*

215.08 – Determination of the Rosette Nebula's Magnetic Field for Different Nebular Shapes

The shape of the HII region of the Rosette Nebula was explored by Celnik (1985), who used several shapes to model the radio brightness temperature data to determine the electron density of the nebula, including a spherical shell with uniform electron density, and a layered shell with varying electron density. Costa, et al, (2016) used Celnik's spherical shell with uniform electron density model to create models for the rotation measure they found from Faraday rotation of extragalactic radio sources. Here, we analyze the Celnik brightness temperature data to determine a root mean square electron density along the line of sight for each pixel for different models of the shape of the HII region and find a distribution of electron densities in the nebula for each model. We use the root mean square electron density along a single line of sight along with the rotation measure along the same line of sight to estimate the magnetic field strength at that location. We will present the resulting magnetic field strengths for several models of the nebula shape.
Author(s): Kara Beauchamp[1], Cole Horan[1], Steven R. Spangler[2], Allison H. Costa[2]
Institution(s): *1. Cornell College, 2. University of Iowa*

215.09 – Stochastic charging of dust grains in protoplanetary disks

Micron-sized dust grains are abundant in the early stages of protoplanetary disks. Not only do such solid particles provide the seeds for planetesimal formation through collisional growth and collective effects, they also modify the overall ionization levels of the surrounding plasma through the accumulation of charge. If the local dust density is large enough that charge is removed from the nebular gas through deposition on grain surfaces, magnetic fields can detach from the gas making the MRI process inoperative. For highly porous dust aggregates, MRI quenching can become even more efficient since porous aggregates accumulate charge more efficiently than do compact spherical grains having the same mass. The primary goal of this work is to develop a numerical model of dust coagulation and charging in a magnetized protoplanetary disk to answer the question: What role does the porosity and/or electrical charge state of dust aggregates play in the magnetohydrodynamic (MHD) structure of protoplanetary disks? The collisional charging of a grain is affected by its surface area and morphology. Here we compare the electron and ion currents incident on micron and submicron aggregate grains made of spherical monomers to the currents incident on spherical grains of equivalent mass. The electrons and ions are absorbed on the dust grain surface at random times; as a result charge fluctuates stochastically. We calculate the average charge and charge probability distribution for (i) aggregates composed of monomers of 10 nm, 20 nm and 50 nm monomers with an effective aggregate radius of 0.1 m, and (ii) aggregates consisting of up to 100 monomers with monomer radius of 0.1 micron. The implications of our results for non-ideal magnetohydrodynamics in protoplanetary disks are briefly discussed in terms of the effect of disk ionization fraction and chemical networks.

Author(s): Khandaker Sharmin Ashrafi[1], Samuel Esparza[1], Chuchu Xiang[1], Lorin Matthews[1], Augusto Carballido[1], Truell Hyde[1]
Institution(s): *1. Baylor University*

215.10 – Modeling the growth of chondrule rims with molecular dynamics

We present a method to investigate the structure of dust rims formed around chondrules as the latter sweep up dust in the nebula gas. We use an N-body code to investigate growth of a chondrule rim through the collision of micron-sized aggregates with a mm-sized spherical body. The code models the detailed collision processes of micron-sized aggregates, taking into account the aggregate morphology, trajectory, and orientation of the colliding grains. The aggregates are formed from silicate spheres with a power law distribution in radius. In each iteration, a dust aggregate is shot towards the chondrule, with the relative velocity between the dust aggregate and chondrule determined by coupling of the particles to the turbulent gas environment. The possible collision outcomes are sticking at the point of contact, bouncing, or rolling on the surface, which results in compaction, as determined by the critical bouncing velocity and critical rolling energy. The resulting chondrule rim is divided into layers for analysis. Preliminary results show that the innermost layer has the highest compactness factor, and the porosity increases with distance from the chondrule center. The size distribution of monomers in each layer shows that the outer layers tend to have a higher ratio of large monomers to small monomers. As the porosity of the dust rim plays an important role in the collision between chondrules, these results provide useful information for predicting compound object growth. As cosmic dust becomes charged in the radiative plasma environment, we will also present results comparing the formation of rims from neutral aggregates and rims formed in an environment where the chondrule and aggregates are charged. Our results will be compared with data from disaggregation of rimmed chondrules in CV chondrites (Paque & Cuzzi 1997), which show a near-linear relation between chondrule radius and rim thickness.

Author(s): Chuchu Xiang[1], Lorin Matthews[1], Augusto Carballido[1], Melissa Morris[2], Truell Hyde[1]
Institution(s): *1. Baylor University, 2. State University of New York*

215.11 – The Relationship Between N(H_{total}) and E(B-V) at High Galactic Latitude

We studied the gas-to-dust ratio at high Galactic latitudes ($|b| \geq 20°$ and 30°). The gas content was measured by the column density of atomic hydrogen from the Leiden/Argentine/Bonn survey and the dust by E(B-V) from the Schlafly et al. (2014) compilation. We do not see significant variation as a function of galactic quadrant or hemisphere. Our results are similar to other studies that used different techniques for deriving N(HI), N(H_2), or E(B-V). Like Liszt (2013), we see a higher slope [N(HI)/E(B-V)] if we choose only those points with E(B-V) ≤ 0.1 mag. We also see the break in slope he noted at 0.08 mag. We examined lines of sight that coincided with the Georgia/Harvard Smithsonian CfA high-latitude CO(1-0) surveys. Although at $|b| \geq 30°$ there were only about 200 CO detections, those points lie systematically below our best fit lines to the data. We can convert the CO line intensities to N(H_2) and determine a global CO-H_2 conversion factor for the high latitude sky.

Author(s): Jessica Erin Doppel[1], Loris A. Magnani[1]
Institution(s): *1. University of Georgia*

215.12 – Hydroxyl as a Tracer of Dark Gas in a Diffuse Molecular Cloud

In an attempt to determine the extent of dark molecular gas at high Galactic latitudes, we have conducted a survey of OH at 18 cm in a region containing the diffuse molecular cloud MBM 53. Dark molecular gas is a term that refers to molecular hydrogen that is either difficult or impossible to detect by conventional spectroscopic means. While models of photo-dissociation regions predict that some molecular hydrogen is found under conditions where other species are too low in abundance to be detected by radio spectroscopy, recent estimates have predicted that as much dark molecular gas exists as that normally detected by CO(1-0) surveys. However, more sensitive surveys either in the CO(1-0) line or other tracers should detect some of this gas. We observed 44 lines of sight at 18 cm to see if very sensitive OH observations could detect some of the dark molecular gas in the Pegasus-Pisces region. Our data were taken with the 305 m Arecibo radiotelescope and have typical rms values of 6-7 mK. We compared our OH observations with the

Georgia/Harvard-Smithsonian CfA high-latitude CO(1-0) survey. Of 8 OH detections at 1667 MHz, 5 were not detected by the CO survey and indicate that at least some of the dark molecular gas may be traced by sensitive OH observations.

Author(s): Josh White[1], Emmanuel Donate[1], Loris A. Magnani[1]
Institution(s): *1. University of Georgia*

215.13 – Recent Hubble Space Telescope Imaging of the Light Echoes of Supernova 2014J in M 82 and Supernova 2016adj in Centaurus A

We report on our ongoing use of Hubble Space Telescope (HST) imaging to monitor the scattered light echoes of recent heavily-extincted supernovae in two nearby, albeit unusual, galaxies.
Supernova 2014J was a highly-reddened Type Ia supernova that erupted in the nearby irregular star-forming galaxy M 82 in 2014 January. It was discovered to have light echo by Crotts (2016) in early epoch HST imaging and has been further described by Yang, et al. (2017) based on HST imaging through late 2014. Our ongoing monitoring in the WFC3 F438W, F555W, and F814W filters shows that, consistent with Crotts (2106) and Yang, et al. (2017), throughout 2015 and 2016 the main light echo arc expanded through a dust complex located approximately 230 pc in the foreground of the supernova. This main light echo has, however, faded dramatically in our most recent HST imaging from 2017 March. The supernova itself has also faded to undetectable levels by 2017 March.
Supernova 2016adj is a highly-reddened core-collapse supernova that erupted inside the unusual dust lane of the nearby giant elliptical galaxy Centaurus A (NGC 5128) in 2016 February. It was discovered to have a light echo by Sugerman & Lawrence (2016) in early epoch HST imaging in 2016 April. Our ongoing monitoring in the WFC3 F438W, F547M, and F814W filters shows a slightly elliptical series of light echo arc segments hosted by a tilted dust complex ranging approximately 150--225 pc in the foreground of the supernova. The supernova itself has also faded to undetectable levels by 2017 April.
References: Crotts, A. P. S., ApJL, 804, L37 (2016); Yang et al., ApJ, 834, 60 (2017); Sugerman, B. and Lawrence, S., ATel #8890 (2016).

Author(s): Stephen S. Lawrence[2], Ali Hyder[2], Ben Sugerman[3], Arlin P. S. Crotts[1]
Institution(s): *1. Columbia University, 2. Hofstra University, 3. Space Science Institute*

216 – Catalogs, Surveys, and Computation Poster Session

216.01 – Exploring ESASky

ESASky is a science-driven discovery portal for all ESA space astronomy missions. It also includes missions from international partners such as Suzaku and Chandra. The first public release of ESASky features interfaces for sky exploration and for single and multiple target searches. Using the application requires no prior-knowledge of any of the missions involved and gives users world-wide simplified access to high-level science-ready data products from space-based Astronomy missions, plus a number of ESA-produced source catalogues, including the Gaia Data Release 1 catalogue. We highlight here the latest features to be developed, including one that allows the user to project onto the sky the footprints of the JWST instruments, at any chosen position and orientation. This tool has been developed to aid JWST astronomers when they are defining observing proposals. We aim to include other missions and instruments in the near future.

Author(s): Guido De Marchi[1]
Institution(s): *1. European Space Agency*
Contributing team(s): ESASky Team

216.02 – The *JWST* North Ecliptic Pole Survey Field for Time-domain Studies

The *JWST* North Ecliptic Pole (NEP) Survey field is located within *JWST*'s northern Continuous Viewing Zone, will span ~14′ in diameter (~10′ with NIRISS coverage) and will be roughly circular in shape (initially sampled during Cycle 1 at 4 distinct orientations with *JWST*/NIRCam's 4.4′×2.2′ FoV — the *JWST* "windmill") and will have NIRISS slitless grism spectroscopy taken in parallel, overlapping an alternate NIRCam orientation. This is the only region in the sky where *JWST* can observe a clean extragalactic deep survey field (free of bright foreground stars and with low Galactic foreground extinction A_V) at arbitrary cadence or at arbitrary orientation. This will crucially enable a wide range of new and exciting time-domain science, including high redshift transient searches and monitoring (e.g., SNe), variability studies from Active Galactic Nuclei to brown dwarf atmospheres, as well as proper motions of extreme scattered Kuiper Belt and Oort Cloud Objects, and of nearby Galactic brown dwarfs, low-mass stars, and ultracool white dwarfs. We therefore welcome and encourage follow-up through GO programs of the initial GTO observations to realize its potential as a *JWST* time-domain community field.
The *JWST* NEP Survey field was selected from an analysis of *WISE* 3.4+4.6 µm, 2MASS JHK_s, and SDSS *ugriz* source counts and of Galactic foreground extinction, and is one of very few such ~10′ fields that are devoid of sources brighter than m_{AB} = 16 mag. We have secured deep (m_{AB} ~ 26 mag) wide-field (~23′×25′) *Ugrz* images of this field and its surroundings with LBT/LBC. We also expect that deep MMT/MMIRS *YJHK* images, deep 3–4.5 GHz VLA and VLBA radio observations, and possibly *HST* ACS/WFC and WFC3/UVIS ultraviolet–visible (pending) and *Chandra*/ACIS X-ray (pending) images will be available before *JWST* launches in Oct 2018.

Author(s): Rolf A Jansen[1]
Institution(s): *1. Arizona State University*

Contributing team(s): the Webb Medium Deep Fields IDS GTO team, the NEPTDS-VLA/VLBA team, and the NEPTDS-Chandra team

216.03 – Multi-Epoch Photometry of Luminous Stars in M31 and M33

Typically, the characteristics of supernovae and supernovae impostor progenitors are pieced together post-hoc from disparate sources after the event. Regular monitoring of luminous stars in nearby galaxies provides a more detailed and uniform source of information about those stars leading up to a significant event.

We present Johnson/Cousins BVRI photometry from the first four years (2012 – 2016) of a targeted ground-based monitoring campaign of luminous stars in M31 and M33 including: likely supernovae and supernovae impostor progenitors, luminous infrared sources, classical LBVs, and warm and cool hypergiants. We have constructed a pipeline capable of quickly mining our images for photometry of additional targets.

The survey will continue to image most of M31 and M33 on an annual basis for the foreseeable future.

Author(s): John C. Martin[1], Roberta M. Humphreys[2]
Institution(s): *1. Univ. of Illinois Springfield, 2. Univ. of Minnesota*

216.05 – Optimal Extraction of Contaminated Slitless Spectroscopy

We present a new formalism for extracting one-dimensional spectra from a collection of slitless spectroscopic images, ideally taken at various position angles and/or dither positions. Our method solves for the spectrum of all the sources simultaneously,hence we inherently correct for contamination from overlapping sources and thereby eliminate the notion of "contamination corrections." Using simulated data, we demonstrate the sensitivity of our algorithm to various instrumental and observational effects, such as astrometric registration, background subtraction, and photometric noise. We also present analysis of HST/WFC3-IR data, which highlights two major advancements over standard extraction-based techniques: (1) increase in spectral resolution without loss in signal-to-noise, and (2) improve spectra for highly contaminated sources. For example, we extract the spectrum of the z~11 galaxy strongly lensed by MACS J0647, and our analysis of this galaxy shows a strong detection of the Lyman break.

Author(s): Russell E. Ryan[1], Stefano Casertano[1], Norbert Pirzkal[1]
Institution(s): *1. STScI*

216.06 – Data Cube Visualization with Blender

With the increasing data acquisition rates from observational and computational astrophysics, new tools are needed to study and visualize data. We present a methodology for rendering 3D data cubes using the open-source 3D software Blender. By importing processed observations and numerical simulations through the Voxel Data format, we are able use the Blender interface and Python API to create high-resolution animated visualizations. We review the methods for data import, animation, and camera movement, and present examples of this methodology. The 3D rendering of data cubes gives scientists the ability to create appealing displays that can be used for both scientific presentations as well as public outreach.

Author(s): Brian R. Kent[1], Matías Gárate[2]
Institution(s): *1. NRAO, 2. Pontificia Universidad Católica de Chile*

216.07 – pyMOOGi - python wrapper for MOOG

pyMOOGi is a python wrapper for MOOG. It allows to use MOOG in a classical, interactive way, but with all graphics handled by python libraries. Some MOOG features have been redesigned, like plotting with *abfind* driver. Also, new funtions have been added, like automatic rescaling of stellar spectrum for *synth* driver. pyMOOGi is an open source project.

Author(s): Monika M Adamow[1]
Institution(s): *1. University of Texas*

216.08 – Introducing the All-sky NOAO Source Catalog

Most 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 only a small fraction have been released to the community via well-calibrated and easily accessible catalogs. We are remedying this by created a catalog of sources from most of the public data taken on CTIO-4m+DECam as well as KPNO-4m+Mosaic3. This catalog, called the NOAO Source Catalog (NSC), already contains 2.3 billion unique objects, 19 billion source measurements, covers ~25,000 square degrees of the sky, has 10-sigma depths of ~23rd magnitude in most broadband filters, and astrometric accuracy of ~20 mas. We plan to release the catalog via the new NOAO Data Lab service in the near future.

Author(s): David L. Nidever[1]
Institution(s): *1. National Optical Astronomy Observatory*
Contributing team(s): NOAO DataLab

217 – Binary Stellar Systems and Pulsating Variable Stars Poster Session

217.01 – The Multiple-component Binary Hyad, vA 351 – a Progress Report

We extend results first announced by Franz et al. (1998) in the abstract, http://adsabs.harvard.edu/abs/1998AAS...19310207F , that identified vA 351 = H346 in the Hyades as a multiple star system containing a white dwarf. With HST/FGS fringe tracking and scanning, spanning four years, we establish a parallax, relative orbit, and mass fraction for the A-B components, with a period, P~5.47y. With ground-based radial velocities from the McDonald Observatory Struve 2.1m telescope and Sandiford Spectrograph, spanning 14 years, we find that component B consists of BC, two M dwarf stars orbiting with a very short period (P(BC)~0.75 days), having a mass ratio C/B~0.94. We confirm that the total mass of the system can only be reconciled with the distance and component photometry by including a fainter, higher mass component, proposed to be a ~0.8Msun white dwarf. Thus, the quadruple system consists of three M dwarfs (A,B,C) and one white dwarf (D). The M dwarf masses and absolute magnitudes are consistent with the Benedict et al. (2016, http://adsabs.harvard.edu/abs/2016AJ....152..141B) lower Main Sequence Mass-Luminosity Relation. The radial velocity signal has so far yielded a signature only for the short-period BC orbital motion. Velocities from H-α and He I emission lines confirm the BC period from absorption lines, with similar (He I) and higher (H-α) velocity amplitudes.

Author(s): George Fritz Benedict[2], Otto G. Franz[1], Lawrence H. Wasserman[1]
Institution(s): *1. Lowell Observatory, 2. Univ. of Texas, Austin*

217.02 – BVRI Photometric Study of the Short Period, Solar Type, Semi-Detached Binary, NSVS 10083189

Precision BVR_cI_c light curves of NSVS 5066754 were taken on 11 nights in February through April 2015 at Dark Sky Observatory in North Carolina with the 0.81-m reflector of Appalachian State University and on 1 night on the SARA 1-m reflector at Kitt Peak National Observatory in remote mode. It is an ~ F8V eclipsing binary with a period of 0.4542238 (2) d. Seven times of minimum light were calculated, for 5 primary and 2 secondary eclipses from our present observations:

HJD I = 2457067.75453±0.0003, 2457088.64907±0.0001, 2457089.55708±0.0001, 2457098.64163±0.0004, 24557113.63117±0.0002
HJD II = 2457066.61874±0.0008, 2457067.52329±0.0017.

In addition, seven observations at minima were introduced as low weighted times of minimum light taken from archived NSVS Data.

The following decreasing quadratic ephemeris was determined from all available times of minimum light in this study covering some 15 years:

JD Hel MinI = 2457089.55665±0.00054d + 0.4542179±0. 0000006 X E - 0.00000000049±0.00000000005 × E^2

We note that this result has a strong level of confidence. This again gives evidence that the components are coming into contact possibly due to magnetic braking as indicated by dark spot activity on the binary.

We initially modeled the B,V,R,I curves simultaneously with the Wilson-Devinney program in a shallow contact configuration (mode 3) as indicated by our Binary Maker 3 fits. This led to a near but non-contact configuration. Next, the general Mode 2 was used to give clues regarding the configuration. During this investigation, the primary component came into contact while the secondary star remained detached. Next, a solution was determined in a semidetached, mode 4 state (larger component filling its critical lobe and the secondary under filing. This may indicate that NSVS 10083189 is coming into contact for the first time. The mode and the period change corroborate.

Our semi-detached, near contact solution, gave a mass ratio of 0.58, with component temperatures of 6250 and 4573 K. A 15° radius cool spot with a t-factor of 0.85 was determined on the primary star. The fill-out of the secondary star was 99%. Further details will be given in our poster paper.

Author(s): Ronald G. Samec[3], Daniel B. Caton[2], Amber Olsen[3], Danny R Faulkner[4], Robert L. Hill[1]
Institution(s): *1. Bob Jones Univ., 2. Dark Sky Observatory, Appalachian State University, 3. Emmanuel College, 4. University of South Carolina, Lancaster*

217.03 – More Surprises from the Eclipsing Cepheid TYC 1031 1262 1

TYC 1031 1262 1 (aka ASAS J182611+1212.6) was the first reported eclipsing Cepheid in the Galaxy (Antipin 2007). In June 2007 AAVSO initiated a campaign to monitor the star and, for the past decade, a sequence of CSB/SJU undergraduate students have continued to monitor this star. In addition to its eclipses and ellipsoidal variation (orbital period: 51.31 ± .01 d) the star has proven to be a bit of a puzzle. It has been classified as type II (Antipin 2007), classical (Schmidt, 2009), and anomalous (Sipahi, 2013). Sipahi measured its radial velocities, found it was a double-lined eclipsing binary, and concluded it consisted of two bright giant stars: F8II+G6II (with masses 1.64 and .93 $M_\odot$). They measured a period *increase* of about 2.5 min yr^{-1} which they associated with mass loss as the Cepheid almost fills its Roche lobe. The AAVSO campaign data and our own data were collected after the data reported by Sipahi and they consistently show a period *decrease* of 1.44 ± .05 min yr^{-1} or a pulse acceleration of 13.3 ± .5 rad/decade^2. Taken together these results suggest period oscillation rather than a secular trend.

Author(s): Thomas W. Kirkman[1]
Institution(s): *1. St. Johns Univ.*

217.04 – Monitoring Period and Amplitude Changes in Classical Cepheids

Cepheid Variable Stars, which are located on the Instability Strip of the Hertzsprung-Russel Diagram, can be used as "standard candle" distance markers (Fiorentino 2007). This came about after the discovery of the Period-Luminosity Relationship (the Leavitt Law), and they have since become a cornerstone of the Cosmic Distance Scale and are helping to further refine the Hubble Constant. Cepheids will cross the Instability Strip, either in a "redward" (cooler) or "blueward" (hotter) direction depending on the stage in which the Cepheid is evolving (Neilson 2012). While Cepheids were originally believed to have regular periods, many are now known to have varying periods, dating back to Eddington (1919). Therefore, Cepheids must be closely monitored in order to deduce where these period variations are coming from - either from inside the star itself or from some outside source. Determining period changes in Cepheids can reveal important information (e.g. evolutionary states, potential companions, etc.).Photometric data were taken for two Cepheids from two different sources and analyzed. The Cepheids in question are AA Gem and BB Gem, both located in the Gemini constellation. Data for these two stars were taken from the All Sky Automated Survey (ASAS) and from the Robotically Controlled Telescope (RCT) at Kitt Peak National Observatory, on which Villanova has guaranteed access. ASAS observes automatically each clear night, and has done so for several years, making it an excellent source for obtaining Cepheid data. The RCT telescope also operates automatically, observing from a preset target list, and achieves a much higher precision than ASAS can. Multi-aperture photometry was performed on the AA Gem and BB Gem RCT images, in Astroimagej. The data were then separated into different seasons, and Fourier fits were applied to the light curves in Kephem (written by Andrej Prša and collaborators). These results were then analyzed via the Hertzsprung Method to find changes in the Cepheids' times of maximum light (and thus periods).

Author(s): Mary Erickson[2], Scott G. Engle[2], Mark Wells[1]
Institution(s): *1. Penn State University, 2. Villanova University*

217.05 – KELT Photometric Observations of R Coronae Borealis Variables

R Coronae Borealis (RCB) stars are low-mass supergiants that are carbon rich and hydrogen poor. They often exhibit stochastic rapid decreases in brightness. Many newly discovered RCB stars have limited photometric observations. The Kilodegree Extremely Little Telescope (KELT) survey is a small aperture, wide-angle, ground-based telescope that provides long baseline photometric observations for up to 10 consecutive years with a typical cadence of 30 minutes. We have identified 13 known RCB stars that have KELT observations. We present light curves of these stars, showing a wide variety of variability, on many timescales and amplitudes. These observations are likely some of the most comprehensive, long-term photometry of RCB stars, making them valuable for further analysis.

Author(s): Krittanon Sirorattanakul[1], Joshua Pepper[1], Geoffrey C. Clayton[2]
Institution(s): *1. Lehigh University, 2. Louisiana State University*

217.06 – H-alpha/H-beta Light Curves for Pulsating Variable Stars

In Joner & Hintz (2015) they discuss the development of a new calibrated H-alpha index similar in nature to the traditional H-beta index. It is demonstrated that the new H-alpha index tracks very well with the equivalent width of the line and the surface temperature. Therefore, we selected a sample of pulsating variable stars to test the possible use of the new index to track temperature changes in those stars over a pulsation cycle. We will present data on a sample of Cepheid, RR Lyrae, and delta Scuti variables. We will also examine changes in the H-alpha index potentially related to period changes in these objects.

Author(s): Eric G. Hintz[1], Michael D. Joner[1], Jonathan Barnes[2]
Institution(s): *1. Brigham Young University, 2. Salt Lake Community College*

217.07 – On the Detection and Characterization of Polluted White Dwarfs

There is evidence of circumstellar material around main sequence, giant, and white dwarf stars. What happens to this material after the main sequence? With this work, we focus on the characterization of the material around WD 1145+017. The goals are to monitor the white dwarf—which has a transiting, disintegrating planetesimal and determine the composition of the evaporated material for that same white dwarf by looking at high-resolution spectra. We also present preliminary results of follow-up photometric observations of known polluted WDs. If rocky bodies survive red giant branch evolution, then the material raining down on a WD atmosphere is a direct probe of main sequence cosmochemistry. If rocky bodies do not survive the evolution, then this informs the degree of post-main-sequence processing. These case studies will provide the community with further insight about debris disk modeling, the degree of post-main-sequence processing of circumstellar material, and the composition of a disintegrating planetesimal.

Author(s): Amy Steele[2], John H. Debes[1], Drake Deming[2]
Institution(s): *1. Space Telescope Science Institute, 2. University of Maryland*

217.08 – Super-Nyquist White Dwarf Pulsations in K2 Long-Cadence Data

The Kepler and K2 missions have recently revolutionized the field of white dwarf asteroseismology. Since white dwarfs pulsate on timescales of order 10 minutes, we aim to observe these objects at K2's short cadence (1 minute). Occasionally we find signatures of pulsations in white dwarf targets that were only observed by K2 at long cadence (30 minute). These signals suffer extreme aliasing since the intrinsic frequencies exceed the Nyquist sampling limit. We present our work to recover accurate frequency determinations for these targets, guided by a limited amount of supplementary, ground-based photometry from McDonald Observatory.

Author(s): Keaton J. Bell[2], JJ Hermes[1], Michael H. Montgomery[2], Zach Vanderbosch[2]
Institution(s): *1. University of North Carolina at Chapel Hill, 2. University of Texas at Austin*

217.09 – The Video Drift Method to Measure Double Stars

A new video method has been developed to measure double stars. The double star components are video recorded as they drift across the camera's field of view from east to west with the telescope's motor drive turned off. Using an existing software program that was specifically written for the analysis of occultation videos (*Limovie - Light Measurement Tool for Occultation Observation using Video Recorder)*, standard (*x*,*y*) coordinates are extracted for each component star for each video frame. An Excel program written by author RLN (*VidPro – Video Drift Program Reduction*) analyses the (*x*,*y*) positions for determining position angle (PA), separation and other statistical quantities. Unlike other double star reduction methods, no star catalogue or calibration doubles are needed as each video drift is self-calibrating. The duration of a typical video for an f/10 telescope system ranges between 20 sec – 1 minute; this along with a 30 frame/sec recording rate produces 100's to 1,000's of (*x*,*y*) pairs for analysis. The video chip's offset from the true east-west direction (drift angle) is computed simultaneously along with a scale factor for each video. The drift angle and scale factor are used with all (*x*,*y*) positions to generate a unique position angle and separation. For 1,800+ doubles measured to date typical standard deviations (our own internal precision) for position angles are 1.1° and for separations 0.35". A comparison was made with the Washington Double Star catalog (WDS) entries that had little or no change in PA and separation for 120 + years. For these doubles our PA's and separations differed by an average of 0.2 deg and 0.2" respectively. Sources of error are discussed along with tips to maximize the quality of the (*x*,*y*) data produced by *Limovie*. *Limovie* and *VidPro* programs are available as free downloads.

Author(s): Richard Nugent[1]
Institution(s): *1. International Occultation Timing Association*

217.10 – Discovery of the Shortest-Period Pre-Cataclysmic Variable

We have determined that the hot white dwarf WD 1202-024 (first identified as SDSS 120515.80-024222.7) is in a very tight orbit with a companion of near brown-dwarf mass of about $0.067M_\odot$. The orbital period of 71.2 minutes is very close to, or somewhat below, the minimum orbital period of cataclysmic variables with H-rich donor stars. However, we find no evidence that this binary is currently, or ever was, transferring mass from the low-mass companion to the white dwarf. We tentatively conclude that this system is a pre-cataclysmic variable (pre-CV) that will become a zero-age CV in less than 250 Myr. Because of the 29-minute integration time of the K2 observations, we use follow-up ground-based photometry to better evaluate the eclipsing light curve. We also utilize the original SDSS spectra, in approximately 15-min segments, to estimate the radial velocity of the white dwarf in its orbit. An analysis of the light curve, with our supplementary constraints, leads to the following system parameters: $M_{wd} \approx 0.41M_\odot$, $R_{wd} \approx 0.021R_\odot$, $M_{com} \approx 0.067M_\odot$, and $R_{com} \approx 0.090R_\odot$, where the subscripts 'wd' and 'com' refer to the white dwarf and low-mass companion, respectively. If our interpretation of this system as a pre-CV is correct, it has the shortest orbital period of any such system found to date, and is predicted to become a compact zero-age CV with a period of about 55 minutes.

Author(s): Lorne A. Nelson[1], Saul A. Rappaport[6], Andrew Vanderburg[4], Bruce Gary[5], Tom Kaye[8], Belinda Kalomeni[3], Steve B. Howell[7], John R. Thorstensen[2]
Institution(s): *1. Bishop's Univ., 2. Dartmouth College, 3. Ege University, 4. Harvard CfA, 5. Hereford Arizona Observatory, 6. MIT, KIASR, 7. NASA Ames Research Center, 8. Raemor Vista Observatory*

300 – George Ellery Hale Prize: The Solar Magnetic Field: From Complexity to Simplicity (and Back), Manfred Schüssler (Max Planck Institute)

300.01 – The solar magnetic field: from complexity to simplicity (and back)

The Sun is the only astrophysical object that permits a detailed study of the basic processes governing its magnetic field. Observations reveal stunning complexity due to the interaction with turbulent convection. Numerical simulations and observations strongly suggest that most of the small-scale field is generated by a process called small-scale dynamo action. The fundamental nature of this process makes it a candidate for magnetic field generation in a broad variety of astrophysical settings.

On the other hand, the global nature of the 11-year cycle (as exhibited, for instance, by the polarity laws of sunspot groups and the regularly reversing axial dipole field) reveals a surprising simplicity. This suggests a description of the global dynamo process underlying the solar cycle in terms of relatively simple concepts. Insufficient knowledge about the structure of magnetic field and flows in the convection zone requires the introduction of a variety of free parameters (or even free functions), which severely impairs the explanatory power of most such models. However, during the last decades, surface observations of plasma flows and magnetic flux emergence, together with studies of magnetic flux transport, provided crucial information about the workings of the dynamo process. They confirm the visionary approach proposed already in the 1960s by Babcock and Leighton. A recent update of their model permits a full study of the space spanned by the few remaining parameters in order to identify the regions with solar-like solutions.

Observations of other cool stars show that the magnetic activity level decreases strongly with stellar rotation rate. The relatively slow rotation of the Sun puts it near to the threshold at which global dynamo action ceases. This suggests a further simplification of the dynamo model in terms of a generic normal form for a weakly nonlinear system. Including the inherent randomness brought about by the flux emergence process leads to a stochastic model whose parameters are fixed by observations. The model results explain the variability of the solar cycle amplitudes from decadal to millennial time scales.
Author(s): Manfred Schüssler[1]
Institution(s): *1. Max-Planck-Institute for Solar System Research*

301 – Stars and Stellar Evolution

301.01D – What we can learn from the variability of Be stars

Be stars are non-supergiant, rapidly rotating B-type stars with emission lines in their spectra. This emission is attributed to a gaseous circumstellar disk, formed from the star itself. These objects are intrinsically variable across a wide range of timescales, and show signatures of pulsation, 'outbursts' (events where material is launched from the stellar surface), variability in the circumstellar environment, and the sudden appearance or disappearance of a circumstellar disk. Using data from the KELT survey (Kilodegree Extremely Little Telescope; a wide-field photometric survey designed to find transiting exoplanets with high precision of ~1% and baselines up to 10 years for ~5 million objects), we investigate the light curves of nearly a thousand Be stars in order to better understand their behavior as a population. We supplement the KELT light curves with infrared and optical spectroscopy for hundreds of these systems to better understand the stellar properties, the circumstellar environment, and the links between them. For systems of particular interest, we investigate the possible links between pulsations and outbursts, search for binary companions, and study the time evolution of the circumstellar environment.
Author(s): Jonathan Labadie-Bartz[1], Joshua Pepper[1], M. Virginia McSwain[1], S. Drew Chojnowski[2]
Institution(s): *1. Lehigh University, 2. New Mexico State University*
Contributing team(s): KELT collaboration

301.02 – Classical Cepheids and real-time stellar evolution

Classical Cepheids are one of the most powerful standard candles available as well as important laboratories for probing stellar evolution. We combine previous measurements of Cepheid rates of period change with recent GAIA parallax measurement to test stellar evolution models against measurements of real-time stellar evolution. We compute new stellar evolution models with different assumptions of convective core overshooting and initial rotation to compare with observed period changes. From this comparison we find that many models are consistent with Cepheid properties but there are some outliers. We discuss some potential explanations for the outliers.
Author(s): Hilding Neilson[1], Cassandra Miller[1]
Institution(s): *1. University of Toronto*

301.03 – DUSTiNGS. III. Distribution of Intermediate-age and Old Stellar Populations in Disks and Outer Extremities of Dwarf Galaxies

As part of the DUST in Nearby Galaxies with Spitzer (DUSTiNGS) survey, we have traced the spatial distributions of intermediate-age and old stars in nine dwarf galaxies in the distant parts of the Local Group. We find intermediate age stars are well mixed with the older populations and extend to large radii, indicating that chemical enrichment from these dust-producing stars may occur in the outer regions of galaxies with some frequency. Theories of structure formation in dwarf galaxies must account for the lack of radial gradients in intermediate-age populations and the presence of these stars in the outer extremities of dwarfs. We also identify the tip of the red giant branch (TRGB) in Spitzer IRAC 3.6 μm photometry. Unlike the constant TRGB in the I band, at 3.6 μm, the TRGB magnitude varies by ~0.7 mag and is not a metallicity independent distance indicator.
Author(s): Kristen B. McQuinn[2], Martha Boyer[1]
Institution(s): *1. Space Telescope Science Institute, 2. University of Texas at Austin*
Contributing team(s): DUSTiNGS Team

301.04 – The Flares of Proxima Cen

The corona of Proxima Cen has been observed with a variety of high-energy instruments (ASCA/SIS, XMM/MOS, XMM/pn, Swift/XRT, Swift/UVOT, Chandra/HRC-I, Chandra/ACIS-S) covering different levels of activity as the star goes through a stellar cycle. The data exhibit numerous strong flares as well as lower level flaring activity. In analogy with the solar case, flare intensities are expected to be scale-free and distributed as a power-law. We have modeled the flare distributions separately for each observation in order to explore their dependence on the energy environment defined by the stellar activity. We find that the flare distribution indices differ considerably, ranging from ≈1.4-2, and discuss the causes of such variations, including dependences on spectral hardness and activity levels.

Author(s): Vinay Kashyap[1], Bradford J. Wargelin[1], Jeremy J. Drake[1], Steven H. Saar[1]
Institution(s): *1. Harvard Smithsonian, CfA*

301.05 – Searching for flares in GALEX data with gPhoton

The Galaxy Evolution Explorer (GALEX) spacecraft observed a large fraction of the sky in two ultraviolet bands using micro-channel plate detectors with time resolutions of less than ten milliseconds. The gPhoton database of calibrated GALEX photon events at MAST has recently enabled a thorough search of this legacy data set for astrophysical variability at cadences shorter than the orbital period of the spacecraft. (https://archive.stsci.edu/prepds/gphoton/) We explore techniques for mining photon-level data for variability on timescales of seconds to minutes with an emphasis on dwarf star flares, which can be probed at lower energies and shorter durations with gPhoton than prior surveys. We present the early results of a systematic search for such events.

Author(s): Chase Million[2], Scott W. Fleming[3], Clara Brasseur[3], Rachel A. Osten[3], Luciana Bianchi[1], Bernie Shiao[3]
Institution(s): *1. Johns Hopkins University, 2. Million Concepts, 3. Space Telescope Science Institute*

301.06 – Results from and Plans for the Two 2017 Solar Eclipses

At this writing fresh from observing the 26 February 2017 annular solar eclipse in exceptionally clear sky from sites in Patagonia, Argentina, we show images from the centerline near Facundo showing Baily's beads and central annularity of the magnitude 99.3% eclipse. From close to the edge of the path from sites north of Facundo within the northern limit (images by Daniel Fischer) and north of Sarmiento at the southern limit (images by Jörg Schoppmeyer), we show unfiltered images that show substantial solar chromosphere with innermost corona above it. We also show SWAP and SDO eclipse images.
For the 21 August 2017 total solar eclipse, we describe our plans for observing coronal structure above the limb from the ground in Oregon and for ultraviolet imaging on the solar disk at the time of the terrestrial eclipse through six filters using the new Solar Ultraviolet Imager (SUVI) on the National Oceanic and Atmospheric Administration's GOES-16 spacecraft, planned along with three similar spacecraft for coronal coverage for the next two decades. SUVI has the biggest overlapping field of view, 53 arcmin square, of any multi-channel space-based EUV imager.
Our research on the 2017 total solar eclipse is supported by grants from the Committee for Research and Exploration of the National Geographic Society and from the Solar Terrestrial Program of the Atmospheric and Geospace Sciences Division of the National Science Foundation. NOAA NCEI are the acronyms for the National Oceanic and Atmospheric Administration's National Centers for Environmental Information.

Author(s): Jay M. Pasachoff[4], Daniel Seaton[2], Michael Kentrianakis[1], Daniel Fischer[3]
Institution(s): *1. AAS 2017 Eclipse Task Force, 2. CIRES/U Colorado, 3. Planetarium Bochum, 4. Williams College*

302 – Bridging Laboratory & Astrophysics: Planetary Physics and Nuclear/Particle Physics

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the interplay between astrophysics with theoretical and experimental studies into the underlying planetary science processes that drive our Universe.

302.01 – Unanticipated physcial processes in the inner coma of 67P/Churyumov-Gerasimenko

Interpreting the spectral emissions of 67P/Churyumov-Gerasimenko has been very difficult due to the unanticipated physical processes in the innermost coma of the comet that strongly affect the emission lines, particularly in the UV and visible. When the comet's activity is low and the spacecraft is close to the nucleus, the relevant processes are driven in large part by electron dissociation rather than photoprocesses. These results are very sensitive to the extrapolation of plasma properties from the spacecraft to the 10s of km closest to the nucleus. There is at lest one instance also of emission being driven by solar wind features. We will describe the phenomenology and the interpretation of a variety of the observations and conclude with some comments on the data, both from the laboratory and the comet, to interpret the observations.

Author(s): Michael F. A'Hearn[1]
Institution(s): *1. University of Maryland*

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

In Titan's atmosphere, a complex organic chemistry occurs between its main constituents, N_2 and CH_4, and leads to the production of larger molecules and solid aerosols.
Here, we present the latest results on the gas and solid phase analyses in the Titan Haze Simulation (THS) experiment, developed on the NASA Ames COSmIC simulation chamber. The THS is a unique experimental platform that allows us to simulate Titan's atmospheric chemistry at Titan-like temperature (200K) by cooling down N_2-CH_4-based mixtures in a supersonic expansion before inducing the chemistry by plasma. Because of the accelerated gas flow in the expansion, the residence time of the gas in the active plasma region is less than 3 μs. This results in a truncated chemistry that enables us to monitor the first and intermediate steps of the chemistry as well as specific chemical pathways when adding, in the initial gas mixture, heavier molecules that have been detected as trace elements on Titan[1]. We discuss the results of recent Mid-infrared (MIR) spectroscopy[2] and X-ray Absorption Near Edge Structure spectroscopy studies of THS Titan tholins produced in different gas mixtures (with and without acetylene and benzene). Both studies have shown the presence of nitrogen chemistry, and differences in the level and nature of the nitrogen incorporation depending on the initial gas mixture. A comparison of THS MIR spectra to VIMS 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.
In addition, a new model has been developed to simulate the plasma chemistry in the THS. Electron impact and chemical kinetics equations for more than 120 species are followed. The calculated mass spectra are in good agreement with the experimental THS mass spectra[1], confirming that the short residence time in the plasma cavity limits the growth of larger species and results in a truncated chemistry, a main feature of the THS.

References:
[1] Sciamma-O'Brien E. et al., Icarus, 243, 325 (2014)
[2] Sciamma-O'Brien E. et al., Icarus, in press (2017)
Author(s): Ella Sciamma-O'Brien[2], Alexander Raymond[1], Eric Mazur[1], Farid Salama[2]
Institution(s): *1. Harvard University, 2. NASA Ames Research Center*

302.03 – Dark Matter Hunters

We know just enough about dark matter to design beautiful and plausible particle models for it, but not enough to sharpen searches in this vast theoretical parameter space. In this talk, I will highlight new ideas from the community to cover this large parameter space, and how new laboratory measurements and techniques are helping the community probe previously inaccessible types of dark matter microphysics. I will discuss open questions and possible future directions.

Author(s): Annika Peter[1]
Institution(s): *1. The Ohio State University*

303 – Preparing for JWST Observations: Insights from Exoplanet, Debris Disk, and Brown Dwarf GTO Programs I

Opportunities to propose Early Release Science (ERS) observations for the James Webb Space Telescope (JWST) are now available. JWST General Observer (GO) program opportunities will be available in just a few months (November 2017). How can you prepare a successful JWST observing program? Here the Guaranteed-Time Observers (GTO) will describe how they turned their science into JWST observing programs, including JWST proposal planning tool use case examples. This session will focus primarily on Exoplanet, Debris Disk, and Brown Dwarf JWST GTO Programs.

303.01 – Exoplanets and debris disk imaging with JWST

Dramatic progress in exoplanetary systems imaging has occurred since the first generation of space coronagraphs on HST (NICMOS, STIS, ACS). While HST remains at forefront of both exoplanetary and circumstellar disk science, ground-based instruments have improved by three orders of magnitudes over the past decade. JWST will extend the current state of the art with a larger set of superior coronagraphs and greater sensitivity across more than a factor of 10 in wavelength, making it extraordinarily capable for detailed imaging characterization of planets and disks. We will address specific questions about nearby exoplanetary systems, while also optimizing observing strategies across the breadth of JWST's high-contrast imaging modes, as follows:

(a) Deep, multi-wavelength observations of selected nearby stars hosting known debris disks & planets. We will use the NIRCam and MIRI coronagraphs across the full range of JWST wavelengths, and perhaps MIRI MRS spatially resolved spectroscopy. Each comprehensive dataset will support a variety of investigations addressing both disk characterization and exoplanet detection & characterization.

(b) Characterization of Planetary Systems around Cool M Stars. We will observe young and dusty M dwarfs, to complement observations of the closer but older M dwarf samples under consideration by other GTO groups. JWST observations will dramatically exceed HST images in their ability to address questions about the properties of dust rings, while the more favorable contrast ratios of planets relative to M dwarf hosts will enable sensitivity to relatively low mass planetary companions.

Author(s): Laurent Pueyo[1], Remi Soummer[1], Marshall D. Perrin[1]
Institution(s): *1. Space Telescope Science Institute*

303.02 – NIRCam Coronagraphic Observations of Disks and Planetary Systems

The NIRCam coronagraph offers a dramatic increase in sensitivity at wavelengths of 3-5 um where young planets are brightest. While large ground-based telescopes with Extreme Adaptive Optics have an advantage in inner working angle, NIRCam's sensitivity will allow high precision photometry for known planets and searches for planets with masses below that of Saturn. For debris disk science NIRCam observations will address the scattering properties of dust, look for evidence of ices and tholins, and search for planets which affect the structure of the disk itself. The NIRCam team's GTO program includes medium-band filter observations of known young planets having 1-5 Jupiter masses. A collaborative program with the MIRI team will provide coronagraphic observations at longer wavelengths. The combined dataset will yield the exoplanet's total luminosity and effective temperature, an estimate of the initial entropy of the newly-formed planet, and the retrieval of atmospheric properties.
The program will also make deep searches for lower mass planets toward known planetary systems, nearby young M stars and debris disk systems. Achievable mass limits range from ~1 Jupiter mass beyond 20 AU for the brightest A stars to perhaps a Uranus mass within 10 AU for the closest M stars. We will discuss details of the coronagraphic program for both the exoplanet and debris disk cases with an emphasis on using APT to optimize the observations of target and reference stars.

Author(s): Charles A. Beichman[1], Marie Ygouf[1], Andras Gaspar[2]
Institution(s): *1. IPAC, 2. Univ of Arizona*
Contributing team(s): NIRCam Science Team

303.03 – The physics of brown dwarfs and exoplanets – JWST/NIRSpec GTO program overview

The Near Infrared Spectrograph (NIRSpec) is one of the science instruments on the James Webb Space Telescope that is scheduled for launch in October 2018. The NIRSpec guaranteed time observer (GTO) team will use ~70 hours of NIRSpec guaranteed time to carry out spectroscopic observations of brown dwarfs as well as transiting and directly imaged exoplanets with NIRSpec. The instrument offers four distinct observing modes to proposers that will all be exercised by the GTO programs presented here: 1) multi object spectroscopy (MOS) of 10s to 100s of sources in a ~9 arcmin field of view (FOV), 2) integral field spectroscopy (IFS) with a 3” x 3” FOV, 3) high contrast slit spectroscopy of individual objects and 4) time series observations of bright sources, e.g. transiting exoplanets host stars. Seven dispersers are available in all observing modes: a prism covering the wavelength range from 0.6 to 5.3 micron with a spectral resolution R of ~30 to 300, and two sets of three gratings covering 0.7 to 5.2 micron with medium (R~1000) and high (R~2700) spectral resolution.
We will present the science goals and targets for the brown dwarf and exoplanet GTO programs and discuss the planned implementation of the observations. The latter might be of particular interest to future JWST/NIRSpec proposers.

Author(s): Stephan Birkmann[1], Catarina Alves de Oliveira[1], Jeff A. Valenti[2], Pierre Ferruit[1]
Institution(s): *1. European Space Agency, 2. STScI*
Contributing team(s): NIRSpec GTO Team

304 – Cosmic Microwave Background

304.01D – Measurements of the CMB Polarization with POLARBEAR and the Optical Performance of the Simons Array

POLARBEAR is a ground-based polarization sensitive Cosmic Microwave Background (CMB) experiment installed on the 2.5 m aperture Gregorian-Dragone type Huan Tran Telescope located in the Atacama desert in Chile. POLARBEAR is designed to conduct broad surveys at 150 GHz to measure the CMB B-mode polarization signal from inflationary gravitational waves at large angular scales and from gravitational lensing at small angular scales. POLARBEAR started observations in 2012. First season results on gravitational lensing B-mode measurements were published in 2014, and the data analysis of further seasons is in progress. In order to further increase measurement sensitivity, in 2018 the experiment will be upgraded to the Simons Array comprising of three telescopes, each with improved receiver optics using alumina lenses. In order to further expand the observational range, the second and third receiver optics designs were further modified for improved optical performance across the frequencies of 95, 150, 220, and 280 GHz. The diffraction limited field of view was increased especially for the higher frequencies to span a full 4.5 degrees diameter field of view of the telescope. The Simons Array will have a total of 22,764 detectors within this field of view. The Simons Array is projected to put strong constraints on both the measurements of the tensor-to-scalar ratio for inflationary cosmology and the sum of the neutrino masses. I will report on the status of current observations and analysis of the first two observation seasons of POLARBEAR as well as the optics design development of the Simons Array receivers.

Author(s): Frederick Takayuki Matsuda[1]
Institution(s): *1. University of California, San Diego*
Contributing team(s): POLARBEAR Collaboration

304.02D – Instrument development of the CMB polarization POLARBEAR-2 experiment

We present the status of the development of the Polarbear-2 (PB-2) and Simons Array experiments.

PB-2 is a ground-based Cosmic Microwave Background (CMB) polarization experiment located at the James Ax observatory in the Atacama desert of Northern Chile. The Simons Array will consist of three PB-2 receivers on three Huan Tran-style telescopes, each containing a multi-chroic detector array. The first new Simons Array receiver, Polarbear- 2A(PB-2A), will be deployed in 2017. The PB-2A focal plane consists of 1,897 lenslet-coupled, dual-polarization, sinuous-antenna-coupled pixels operating at 95 and 150 GHz, making a total of 7,588 polarization-sensitive transition edge sensor (TES) bolometers. In the order to cover both frequencies, we developed broadband two layer anti-reflection (AR) coating for 5.345 mm diameter lenslets using two types of epoxy: Stycast2850FT and Stycast1090. We developed a mass production AR coating methodology that can control the uniformity and shape to within 25 μm error from the designed value. The second (PB-2B) and third (PB-2C) receivers will employ similar technologies and will cover 95, 150, 220 and 280 GHz. The Simons Array will survey 80% of the sky with broad frequency coverage and high resolution, making it a powerful tool to constrain the tensor-to-scalar ratio through measurements of primordial B-modes and the sum of the neutrino masses through measurements of B-modes produced by gravitational lensing.

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Contributing team(s): POLARBEAR collaboration

304.04 – Post-reionization Kinetic Sunyaev-Zel'dovich Signal in the Illustris simulation

Using Illustris, a state-of-art cosmological simulation of gravity, hydrodynamics, and star-formation, we revisit the calculation the angular power spectrum of the kinetic Sunyaev-Zel'dovich effect from the post-reionization ($z < 6$) epoch by Shaw et al. (2012). We not only report the updated value given by the analytical model used in previous studies, but go over the simplifying assumptions made in the model. The assumptions include using gas density for free electron density and neglecting the connected term arising due to the fourth order nature of momentum power spectrum that sources the signal. With these assumptions, Illustris gives slightly (~ 10%) larger signal than in their work. Then, the signal is reduced by ~ 20% when using actual free electron density in the calculation instead of gas density. This is because larger neutral fraction in dense regions results in loss of total free electron and suppression of fluctuations in free electron density. We find that the connected term can take up to half of the momentum power spectrum at $z < 2$. Due to a strong suppression of low-z signal by baryonic physics, the extra contribution from the connected term to ~ 10% level although it may have been underestimated due to the finite box-size of Illustris. With these corrections, our result is very close to the original result of Shaw et al. (2012), which is well described by a simple power-law, D_l = 1.38[l/3000]0.21 μK^2, at 3000 < l < 10000.

Author(s): Hyunbae Park[2], Marcelo A. Alvarez[1], John Richard Bond[1]
Institution(s): *1. Canadian Institute for Theoretical Astrophysics, 2. Korea Astronomy and Space Science Institute*

305 – Plenary Talk: CANDELS: A Cosmic Quest for Distant Galaxies Offering Live Views of Galaxy Evolution, David Koo (University of California, Santa Cruz)

305.01 – CANDELS: A Cosmic Quest for Distant Galaxies Offering Live Views of Galaxy Evolution

For decades, the study of distant galaxies has been pushing the frontiers of extra-galactic research, with observations from the best suite of telescopes and instruments and with theory from the most advanced computer simulations. This talk will focus on observations taken within the CANDELS fields to reveal the richness and complexity of this still-growing field. CANDELS (Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey) itself is the largest project ever taken by Hubble and is composed of optical and near-infrared images of five tiny regions of sky containing over 200,000 distant galaxies. All these regions, two of which are GOODS North and South, were already outstanding in possessing years of prior surveys taken by many teams worldwide and have continued to attract more and better spectra and panchromatic images from Keck, Hubble, Chandra, Spitzer, and other telescopes ranging from X-ray to radio. Combined together, the rich data within the CANDELS fields offer live views of galaxy evolution from “Cosmic Dawn” when the first infant galaxies and cosmic black holes were born, through “Cosmic Noon” during the peak of galaxy and black hole growth, and then to “Cosmic Afternoon” when star formation and black hole activities, morphologies, motions, and contents settled to those of our Milky Way and its zoo of cousins today. The talk will highlight some interesting discoveries from the last two periods and close with new mysteries challenging our field in the 21st century and future prospects for solving them.

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Contributing team(s): CANDELS

307 – Star Formation and Open Clusters

307.01 – What Determines Star Formation Rates?

The relations between star formation and gas have received renewed attention. We combine studies on scales ranging from local (within 0.5 kpc) to distant galaxies to assess what factors contribute to star formation. These include studies of star forming regions in the Milky Way, the LMC, nearby galaxies with spatially resolved star formation, and integrated galaxy studies. We test whether total molecular gas or dense gas provides the best predictor of star formation rate. The star formation ``efficiency," defined as star formation rate divided by mass, spreads over a large range when the mass refers to molecular gas; the standard deviation of the log of the efficiency decreases by a factor of three when the mass of relatively dense molecular gas is used rather than the mass of all the molecular gas. We suggest ways to further develop the concept of "dense gas" to incorporate other factors, such as turbulence.

Author(s): Neal John Evans[1]
Institution(s): *1. The University of Texas at Austin*

307.02 – CO in Protostars (COPS): *Herschel*-SPIRE Spectroscopy of Embedded Protostars

Molecular emission from early stage protostars reveals the properties of the surrounding gas and the underlying physical processes that govern the early stage of star formation. The CO in Protostars (COPS) *Herschel* program observes 27 embedded protostars with SPIRE, including several molecular species, such as CO, ^{13}CO, H_2O, and HCO^+, allowing us to investigate the processes that regulate the early stage of star formation across a large sample of sources. We detect CO rotational lines from J_{up} = 4 to 36, ^{13}CO lines from J_{up} = 5 to 10, and six H_2O lines, along with atomic lines, such as [N II] and [C I]. We have created an uniformly calibrated dataset with the data from Dust, Ice, and Gas In Time (DIGIT) *Herschel* Key Program and archival photometry, in which we characterize each source by its spectral energy distribution and evolutionary class. We detect 323 lines from 25 sources from which we successfully extracted 1D spectra, and 3068 lines from 27 sources observed in all spatial pixels of SPIRE. We analyze the correlations of the line strengths of every line pair from all lines detected in our sample with two methods from ASURV package, Spearman's ρ, which test whether the line strengths relation can be described by a monotonic function, and the Kendall z-value, which quantifies the similarity of the ordering of the line strengths of two lines. We notice that the distribution of correlations shows a systematic tendency coinciding with the wavelength coverages of the instruments, suggesting an instrumental bias. Within each module, the correlations of two CO line pairs show high correlations, which decrease as the difference of the upper *J*-level of the two CO lines increases. The smooth gradients of the distribution of correlations hint that the temperature and density of CO gas are continuously varying throughout the embedding envelope. If all CO gas in the envelope shares a same temperature or density, the correlations would be strong for two CO lines originating from two very different *J*-levels. We find no obvious clustering in the distribution of correlation strength, while a group of CO lines could have shown particularly strong correlations if their properties were dominated by the same physical process.

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Contributing team(s): COPS team

307.03 – When Feedback Fails: The Scaling and Saturation of Star Formation Efficiency

We present a suite of 3D multi-physics MHD simulations following star formation in isolated turbulent molecular gas disks ranging from 5 to 500 parsecs in radius. These simulations are designed to survey the range of surface densities between those typical of Milky Way GMCs (~100 $M_{\odot}pc^{-2}$) and extreme ULIRG environments (~$10^4 M_{\odot}pc^{-2}$) so as to map out the scaling of star formation efficiency (SFE) between these two regimes. The simulations include prescriptions for supernova, stellar wind, and radiative feedback, which we find to be essential in determining both the instantaneous (ϵ_{ff}) and integrated (ϵ_{int}) star formation efficiencies. In all simulations, the gas disks form stars until a critical stellar mass has been reached and the remaining gas is blown out by stellar feedback. We find that surface density is the best predictor of ϵ_{int} of all of the gas cloud's global properties, as suggested by analytic force balance arguments from previous works. Furthermore, SFE eventually saturates to ~1 at high surface density, with very good agreement across different spatial scales. We also find a roughly proportional relationship between ϵ_{ff} and ϵ_{int}. These results have implications for star formation in galactic disks, the nature and fate of nuclear starbursts, and the formation of bound star clusters. The scaling of ϵ_{ff} also contradicts star formation models in which ϵ_{ff}~1% universally, including popular subgrid models for galaxy simulations.

Author(s): Michael Y Grudic[1], Philip F. Hopkins[1], Claude-Andre Faucher-Giguere[3], Eliot Quataert[4], Norman W. Murray[2], Dusan Keres[5]
Institution(s): *1. Caltech, 2. Canadian Institute for Theoretical Astrophysics, 3. Northwestern University, 4. UC Berkeley, 5. UC San Diego*

307.04 – The Cluster Environment of Two High-mass Protostars

Characterizing the environment and stellar population in which high-mass stars form is an important step to decide between the main massive star formation theories. In the monolithic collapse model, the mass of the core will determine the final stellar mass (e.g., McKee & Tan 2003). In contrast, in the competitive accretion model (e.g., Bonnell & Bate 2006), the mass of the high-mass star is related to the properties of the cluster. As dynamical processes

substantially affect the appearance of a cluster, we study early stages of high-mass star formation. These regions often show extended emission from hot dust at infrared wavelengths, which can cause difficulties to define the cluster. We use a multi-wavelength technique to study nearby high-mass star clusters, based on X-ray observations with the Chandra X-Ray Telescope, in conjunction with infrared data and VLA data. The technique relies on the fact that YSOs are particularly bright in X-ray and that contamination is relatively small. X-ray observations allow us to determine the cluster size. The cluster membership and YSOs classification is established using infrared identification of the X-ray sources, and color-color and color-magnitude diagrams.
In this talk, I will present our findings on the cluster study of two high-mass star forming regions: IRAS 20126+4104 and IRAS 16562-3959. While most massive stars appear to be formed in rich a cluster environment, those two sources are candidates for the formation of massive stars in a relatively poor cluster. In contrast to what was found in previous studies (Qiu et al. 2008), the dominant B0-type protostar in IRAS 20126+4104 is associated with a small cluster of low-mass stars. I will also show our current work on IRAS 16562-3959, which contains one of the most luminous O-type protostars in the Galaxy. In the vicinity of this particularly interesting region there is a multitude of small clusters, for which I will present how their stellar population differ from the high-mass star-forming cluster IRAS 16562-3959.
Author(s): Virginie Montes[1], Peter Hofner[1]
Institution(s): *1. New Mexico Institute of Mining and Technology*

307.05 – A VLA Survey of Orion Class 0 Protostars at 30 AU Resolution

We present initial results from the VANDAM:Orion survey, a VLA survey of Class 0 protostars in Orion. Disks and multiple systems are thought to originate early in the star formation process, when the protostars are deeply embedded in dense envelopes. The VANDAM survey of the Perseus molecular cloud demonstrated that VLA Ka-band (33 GHz) observations can resolve disks and companions around Class 0 protostars, providing the means to study the incidence and separations of companions, and the properties of disks during the first 100,000 years of protostellar evolution. The VANDAM:Orion survey targets 92 Class 0 protostars in the Orion Molecular clouds, the largest population of Class 0 objects within 500 pc of the Sun. These were selected from protostars characterized by the Herschel Orion Protostar Survey, or HOPS, which assembled 1.6-870 micron SEDs of 319 protostars in the Orion A and B molecular clouds. VANDAM:Orion not only triples the number of Class 0 protostars observed with the VLA , as compared to the original VANDAM survey, but also samples the diverse environments found in the Orion clouds. VANDAM:Orion also includes 38 Class I protostars found near the targeted Class 0 objects. VANDAM:Orion initially carried out VLA observations in the C-array to determine their fluxes in the Ka-band (33 GHZ). The subsequent A-array observations then imaged the protostars with a resolution of 0.08”/34 AU. The entire sample has now been observed and reduced. We will overview the detection statistics and show examples of multiple systems and disks around Orion Class 0 protostars. The VLA images will also be compared to images from a recent ALMA 850 micron snapshot survey of all Orion protostars characterized by HOPS. Many sources appear opaque to ALMA at 870 μm, but the dust is optically thin for the VLA, enabling it to detect structure that ALMA cannot. Finally, we will discuss the prospects of VANDAM:Orion for characterizing the role of environment in the formation of multiple systems and disks.

Support for this work was provided by the NSF through a Student Observing Support award for proposal VLA 16A-197 from the NRAO.
Author(s): Nicole Karnath[6], John J. Tobin[5], Joseph J. Booker[6], Erin Guilfoil Cox[4], Ana Diaz-Rodriguez[3], MIHKEL Kama[8], Zhi-Yun Li[7], Leslie Looney[4], Carl Melis[2], Nadia Murillo[8], Magnus Persson[8], Nick Reynolds[5], Sarah Sadavoy[1], Dominique Segura-Cox[4], Brian Stephenson[5], Samuel Thomas Megeath[6]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. University of California at San Diego, 3. University of Havana, 4. University of Illinois at Urbana-Champaign, 5. University of Oklahoma, 6. University of Toledo, 7. University of Virginia, 8. Univsersity of Leiden*

307.06D – The Open Cluster Chemical Abundances and Mapping (OCCAM) Survey: Galactic Neutron Capture Abundance Gradients

The evolution of elements, as a function or age, throughout the Milky Way disk provides a key constraint for galaxy evolution models. In an effort to provide these constraints, we have conducted an investigation into the r- and s- process elemental abundances for a large sample of open clusters as part of an optical follow-up to the SDSS-III/APOGEE-1 survey. Stars were identified as cluster members by the Open Cluster Chemical Abundance & Mapping (OCCAM) survey, which culls member candidates by radial velocity, metallicity and proper motion from the observed APOGEE sample. To obtain data for neutron capture elements in these clusters, we conducted a long-term observing campaign covering three years (2013-2016) using the McDonald Observatory Otto Struve 2.1-m telescope and Sandiford Cass Echelle Spectrograph (R ~ 60,000). We present Galactic neutron capture abundance gradients using 30+ clusters, within 6 kpc of the Sun, covering a range of ages from ~80 Myr to ~10 Gyr .

Author(s): Julia O'Connell[3], Peter M. Frinchaboy[3], Matthew D. Shetrone[4], Matthew Melendez[3], Katia Cunha[2], Steven R. Majewski[5], Gail Zasowski[1]
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Contributing team(s): APOGEE Team

308 – Bridging Laboratory & Astrophysics: Plasma Physics

Laboratory astrophysics is the Rosetta Stone that enables astronomers to understand and interpret the cosmos. This session will focus on the interplay between astrophysics with theoretical and experimental studies into the underlying plasma processes that drive our Universe.

308.01 – LAD Early Career Prize Talk:Laboratory astrophysics experiments investigating the effects of high energy fluxes on Rayleigh-Taylor instability growth relevant to young supernova remnants

Energy-transport effects can alter the structure that develops as a supernova evolves into a supernova remnant. The Rayleigh Taylor (RT) instability is thought to produce structure at the interface between the stellar ejecta and the circumstellar matter (CSM), based on simple models and hydrodynamic simulations. When a blast wave emerges from an exploding star, it drives a forward shock into the CSM and a reverse shock forms in the expanding stellar ejecta, creating a young supernova remnant (SNR). As mass accumulates in the shocked layers, the interface between these two shocks decelerates, becoming unstable to the RT instability. Simulations predict that RT produces structures at this interface, having a range of spatial scales. When the CSM is dense enough, as in the case of SN 1993J, the hot shocked matter can produce significant radiative fluxes that affect the emission from the SNR. Here we report experimental results from the National Ignition Facility (NIF) to explore how large energy fluxes, which are present in supernovae such as SN 1993J, might affect this structure. The experiment used NIF to create a RT unstable interface subject to a high energy flux by the emergence of a blast wave into lower-density matter, in analogy to the SNR. We also preformed and with a low energy flux to compare the affect of the energy flux on the instability growth. We found that the RT growth was reduced in the experiments with a high energy flux. In analyzing the comparison with SN 1993J, we discovered that the energy fluxes produced by heat conduction appear to be larger than the radiative energy fluxes, and large enough to have dramatic consequences. No reported astrophysical simulations have included radiation and heat conduction self-consistently in modeling SNRs.

Author(s): Carolyn C. Kuranz[7], R. Paul Drake[7], Hye Sook Park[3], Channing Huntington[3], Aaron R. Miles[3], Bruce A. Remington[3], Tomek Plewa[1], Matt Trantham[7], Dov Shvarts[7], Kumar Raman[3], Steven MacLaren[3], Wesley Wan[7], Forrest Doss[4], John Kline[4], Kirk Flippos[4], Guy Malamud[7], Timothy Handy[7],Shon Prisbey[3], Michael Grosskopf[6], Christine Krauland[2], Sallee Klein[7], Eric Harding[5], Russell Wallace[3], Donna Marion[7], Dan Kalantar[3]
Institution(s): *1. Florida State University, 2. General Atomics, 3. Lawrence Livermore National Laboratory, 4. Los Alamos National Laboratory, 5. Sandia National Laboratory, 6. Simon Fraser University, 7. University of Michigan*

308.02 – Challenges and opportunities in laboratory plasma astrophysics

We are in a period of explosive success and opportunity in the laboratory study of plasma phenomena that are relevant to astrophysics. In this talk I will share with you several areas in which recent work, often foreshadowed 20 or 30 years ago, has produced dramatic initial success with prospects for much more. To begin, the talk will provide a brief look at the types of devices used and the regimes they access, showing how they span many orders of magnitude in parameters of interest. It will then illustrate the types of work one can do with laboratory plasmas that are relevant to astrophysics, which range from direct measurement of material properties to the production of scaled models of certain dynamics to the pursuit of complementary understanding. Examples will be drawn from the flow of energy and momentum in astrophysics, the formation and structure of astrophysical systems, and magnetization and its consequences. I hope to include some discussion of collisionless shocks, very dense plasmas, work relevant to the end of the Dark Ages, reconnection, and dynamos. The talk will conclude by highlighting some topics where it seems that we may be on the verge of exciting new progress.

The originators of work discussed, and collaborators and funding sources when appropriate, will be included in the talk.

Author(s): R. Paul Drake[1]
Institution(s): *1. Univ. of Michigan*

308.03 – Laboratory Observation of High-Mach Number, Laser-Driven Magnetized Collisionless Shocks

Collisionless shocks are common phenomena in space and astrophysical systems, including solar and planetary winds, coronal mass ejections, supernovae remnants, and the jets of active galactic nuclei, and in many the shocks are believed to efficiently accelerate particles to some of the highest observed energies. Only recently, however, have laser and diagnostic capabilities evolved sufficiently to allow the detailed study in the laboratory of the microphysics of collisionless shocks over a large parameter regime. We present the first laboratory generation of high-Mach number magnetized collisionless shocks created through the interaction of an expanding laser-driven plasma with a magnetized ambient plasma. Time-resolved, two-dimensional imaging of plasma density and magnetic fields shows the formation and evolution of a supercritical shock propagating at magnetosonic Mach number $M_{ms} \approx 12$. Particle-in-cell simulations constrained by experimental data further detail the shock formation and separate dynamics of the multi-ion-species ambient plasma. The results show that the shocks form on timescales as fast as one gyroperiod, aided by the efficient coupling of energy, and the generation of a magnetic barrier, between the piston and ambient ions. The development of this experimental platform complements present remote sensing and spacecraft observations, and opens the way for controlled laboratory investigations of high-Mach number collisionless shocks, including the mechanisms and efficiency of particle acceleration. The platform is also flexible, allowing us to study shocks in different magnetic field geometries, in different ambient plasma conditions, and in relation to other effects in magnetized, high-Mach number plasmas such as magnetic reconnection or the Weibel instability.

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Institution(s): *1. Laboratory for Laser Energetics, 2. PPPL, 3. Princeton University, 4. University of Michigan, Ann Arbor, 5. University of New Hampshire*

308.04 – Measuring the radiative properties of astrophysical matter using the Z X-ray source

The Z Astrophysical Plasma Properties (ZAPP) collaboration is staging Z experiments that simultaneously investigate multiple topics in radiative properties of hot dense matter. The four astrophysics questions presently guiding this research are: 1) Why can't we predict the location of the convection zone base in the Sun?; 2) How does radiation transport affect spectrum formation in accretion-powered objects?; 3) Why doesn't spectral fitting provide the correct properties for White Dwarfs?; and 4) Why can't we predict the heating and charge state distribution in photoionized plasmas? Recent progress using Z, the most energetic x-ray source on earth, to address these questions will be described. We emphasize the first two topics. Opacity models are an essential ingredient of stellar models and are highly sophisticated, but laboratory opacity tests have only now become possible at the conditions existing inside stars. Our opacity research emphasizes measuring iron at conditions relevant to the base of the solar convection zone, where the electron temperature and density are believed to be 190 eV and 9×10^{22}e/cc, respectively. The results exhibit large disagreements between iron opacity measurements and models and ongoing research is aimed at testing hypotheses for this discrepancy. The second project is motivated by the fact that emission lines from L-shell ions are not observed from iron in black hole accretion disks, but are observed from silicon in x-ray binaries. These disparate observations may be explained by differences in the radiation transport within the plasmas, but models for the spectral line formation and transport in photoionized plasmas have never been tested. We investigate photoionized silicon plasmas using absorption spectroscopy to infer the plasma conditions and emission spectroscopy to determine the dependence of spectral emission on plasma column density.
++Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

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Institution(s): *1. Sandia National Laboratories*
Contributing team(s): ZAPP Team

309 – Preparing for JWST Observations: Insights from Exoplanet, Debris Disk, and Brown Dwarf GTO Programs II

Opportunities to propose Early Release Science (ERS) observations for the James Webb Space Telescope (JWST) are now available. JWST General Observer (GO) program opportunities will be available in just a few months (November 2017). How can you prepare a successful JWST observing program? Here the Guaranteed-Time Observers (GTO) will describe how they turned their science into JWST observing programs, including JWST proposal planning tool use case examples. This session will focus primarily on Exoplanet, Debris Disk, and Brown Dwarf JWST GTO Programs.

309.01 – Characterizing transiting exoplanet atmospheres using NIRCam grism spectra

JWST will enable high signal-to-noise spectroscopic observations of the atmospheres of transiting planets with high sensitivity at wavelengths that are inaccessible with HST or other existing facilities. We plan to exploit this by measuring abundances, chemical compositions, cloud properties, and temperature-pressure parameters of a set of mostly warm (T ~ 600 - 1200 K) and low mass (14 - 200 Earth mass) planets in our guaranteed time program. These planets are expected to have significant molecular absorptions of H_2O, CH_4, CO_2, CO, and other molecules that are key for determining these parameters and illuminating how and where the planets formed. We describe how we will use the NIRCam grisms to observe slitless transmission and emission spectra of these planets over 2.4 - 5.0

microns wavelength and how well these observations can measure our desired parameters. This will include how we set integration times, exposure parameters, and obtain simultaneous shorter wavelength images to track telescope pointing and stellar variability. We will illustrate this with specific examples showing model spectra, simulated observations, expected information retrieval results, completed Astronomer's Proposal Tools observing templates, target visibility, and other considerations.

Author(s): Thomas P. Greene[2], Everett Schlawin[4], Charles A. Beichman[3], Michael R. Line[1], Jonathan J Fortney[5], Jonathan Fraine[4]
Institution(s): *1. Arizona State University, 2. NASA Ames Research Center, 3. NASA Exoplanet Science Institute, 4. University of Arizona, 5. University of California at Santa Cruz*
Contributing team(s): JWST NIRCam Team

309.02 – Characterizing Rosetta Stone Exoplanets with JWST Transit Spectroscopy

JWST will for the first time provide for spectroscopic (R > 100) observation of systems hosting transiting exoplanets over the critical wavelength range from 0.6 to 28.5 microns. Our team will take advantage of JWST's spectral coverage and resolution to characterize a small number of exoplanets in exquisite detail. We plan to focus our efforts on single representative members of the hot-Jupiter, warm-Neptune, and temperate-Earth populations in both transmission and emission over the full wavelength range of JWST. Our JWST observations will hopefully become 'Rosetta Stones' that will serve as benchmarks for further observations of planets within each representative population and a lasting legacy of the JWST mission. Here we will describe our observational plan and how we turned our science goals into an implemented Cycle 1 JWST program.

Author(s): Nikole K. Lewis[4], Mark Clampin[3], Sara Seager[2], Jeff A. Valenti[4], Matt Mountain[1]
Institution(s): *1. AURA, 2. MIT, 3. NASA GSFC, 4. STScI*
Contributing team(s): JWST Telescope Scientist GTO Team

309.03 – Towards Precise Constraints on the Chemical Compositions and Thermal Structures of Giant Exoplanets with a JWST GTO Program

The chemical compositions and thermal structures of close-in planets are two of the major questions raised over the last 15+ years of exoplanet atmospheric characterization. These are fundamental questions in their own right, and answering them also has the potential to improve our understanding of the planets in the Solar System. JWST offers the opportunity to make a major advance on these topics by revealing a more complete and accurate inventory of the chemical species in exoplanet atmospheres and by precisely measuring atmospheric temperatures over a broad range of pressures. I will describe how we plan to use an Interdisciplinary Scientist GTO program to determine the compositions and thermal structures of transiting, hot giant exoplanets using dayside thermal emission measurements obtained at secondary eclipse. Our composition measurements are focused on determining absolute molecular abundances as a tracer of atmospheric metallicity and the abundance ratio of carbon to oxygen. The targets in our program have a range of masses and irradiation, which will enable us to test theories of how atmospheric metallicity varies with planet mass and how thermal structures respond to different levels of stellar forcing.

Author(s): Jacob Bean[2], Jonathan I. Lunine[1]
Institution(s): *1. Cornell University, 2. University of Chicago*

309.04 – Exoplanet and brown dwarf atmosphere characterization with NIRISS SOSS

The SOSS mode of NIRISS offers a unique combination of wide wavelength coverage (0.6-2.8 μm), medium resolving power (R=500-2000), and slit-less operation that makes it powerful for time series observations aimed at characterizing the atmosphere of exoplanets and brown dwarfs. In this talk I will present the NIRISS GTO team plan to obtain NIRISS SOSS transit and eclipse observations of a sample of 14 exoplanets that span the full available range of equilibrium temperatures (300-3000 K) and masses (1 M_{Earth} - 10 M_{Jup}) for planets amenable to atmospheric characterization. Our observations will measure the abundance of the molecules and aerosols present in the exoplanets' atmosphere and determine the vertical temperature structure of the hottest targets. These results will allow us to address fundamental issues such as the formation process and formation location of these close-in planets, the presence and characteristics of particulate clouds, and non-equilibrium chemistry effects that might be at play in their atmosphere. Four of our targets are rocky and for these we intend to place some of the first constraints on the mean molecular weight, and hence bulk composition, of their atmospheres. For one target, we will acquire observations continuously throughout a full orbital period to constrain its temperature-pressure profile as a function of longitude and study how heat is absorbed and redistributed in its atmosphere. Finally, we will also observe a variable early-T dwarf continuously for a complete rotation period, to study the vertical extent of its dust clouds and the upwelling processes happening in its atmosphere. I will present how we developed our plan, highlighting some important considerations specific to SOSS observations, as well as some tools that are publicly available to help potential users plan their own SOSS observations.

Author(s): David Lafreniere[1]
Institution(s): *1. University of Montreal*
Contributing team(s): JWST NIRISS GTO team

310 – Cosmology

310.01 – Probing Cosmological Reionization with the High-redshift Lyman-alpha Forest

When the first galaxies emerged, ~100 - 500 million years after the Big Bang, their starlight likely reionized and heated the intergalactic hydrogen that had existed since cosmological recombination. Much is currently unknown about this process, including what spatial structure it had, when it started and completed, and even which sources drove it. In this talk, I will discuss what recent and upcoming observations of the high-redshift Lyman-alpha forest could tell us about the reionization process.

Author(s): Anson D'Aloisio[2], Matthew McQuinn[2], Hy Trac[1]
Institution(s): *1. Carnegie Mellon University, 2. University of Washington*

310.02 – Banging Galaxy Clusters: High Fidelity X-ray Temperature and Radio Maps to Probe the Physics of Merging Clusters

We present early results from an X-ray/Radio study of a sample of merging galaxy clusters. Using a novel X-ray pipeline, we have generated high-fidelity temperature maps from existing long-integration Chandra data for a set of clusters including Abell 115, A520, and MACSJ0717.5+3745. Our pipeline, written in python and operating on the NASA ARC high performance supercomputer Pleiades, generates temperature maps with minimal user interaction. This code will be released, with full documentation, on GitHub in beta to the community later this year. We have identified a population of observable shocks in the X-ray data that allow us to characterize the merging activity. In addition, we have compared the X-ray emission and properties to the radio data from observations with the JVLA and GMRT. These merging clusters contain radio relics and/or radio halos in each case. These data products illuminate the merger process, and how the energy of the merger is dissipated into thermal and non-thermal forms. This research was supported by NASA ADAP grant NNX15AE17G.

Author(s): Jack O. Burns[1], Eric J. Hallman[1], Brian Alden[1], Abhirup Datta[1], David Rapetti[1]
Institution(s): *1. Univ. of Colorado at Boulder*

310.03 – Entropy, gas fraction, and temperature scaling relations of galaxy clusters and groups at R_{200}

With the growing number of galaxy clusters and groups measured in X-ray out to R_{200}, it is possible to study the scaling relations between the enclosed gas fraction ($f_{gas,200}$), entropy (K_{200}), and temperature (T_{500}), where the gas fraction and entropy are of great interest to constrain cosmological parameters and to understand the thermodynamic history of clusters or group formations, respectively. We will present scaling relations using 22 groups and clusters with published X-ray data in the literature. The power law slope of the K_{200}-T_{200} relation is 0.638+/-0.205, which is shallower than the gravity heating-only baseline model of 1 and the K_{200}-T_{200} relation. For massive clusters (T_{200} > 2 to 3 keV), K_{200} is lower than the baseline model, while no such entropy deficit was found for low-mass groups. The entropy deficit at R_{200} for massive clusters cannot be fully accounted for by the bias or deviation in the gas fraction. The enclosed baryon fraction at R_{200} is broadly consistent with the cosmic value. Physical properties of the outskirts of individual clusters, e.g., the nearest non-cool core cluster, Antlia, and a massive cluster, Abell 1689, will also be highlighted.

Author(s): Ka-Wah Wong[1], Jimmy Irwin[5], Daniel R. Wik[2], Ming Sun[6], Craig L. Sarazin[7], Yutaka Fujita[3], Thomas Reiprich[4]
Institution(s): *1. Minnesota State University, Mankato, 2. NASA/Goddard Space Flight Center, 3. Osaka University, 4. Universität Bonn, 5. University of Alabama - Tuscaloosa, 6. University of Alabama in Huntsville, 7. University of Virginia*

310.04 – Measurements of the pairwise kinematic Sunyaev-Zel'dovich effect with the Atacama Cosmology Telescope and future surveys

We have made improved measurements of the kinematic Sunyaev-Zel'dovich (kSZ) effect using data from the Atacama Cosmology Telescope (ACT) and the Baryon Oscillation Spectroscopic Survey (BOSS). We used a map of the Cosmic Microwave Background (CMB) from two seasons of observations each by ACT and the Atacama Cosmology Telescope Polarimeter (ACTPol) receiver. We evaluated the mean pairwise baryon momentum associated with the positions of 50,000 bright galaxies in the BOSS DR11 Large Scale Structure catalog via 600 square degrees of overlapping sky area. The measurement of the kSZ signal arising from the large-scale motions of clusters was made by fitting data to an analytical model. The free parameter of the fit determined the optical depth to microwave photon scattering for the cluster sample. We estimated the covariance matrix of the mean pairwise momentum as a function of galaxy separation using CMB simulations, jackknife evaluation, and bootstrap estimates. The most conservative simulation-based uncertainties gave signal-to-noise estimates between 3.6 and 4.1 for various luminosity cuts. Additionally, we explored a novel approach to estimating cluster optical depths from the average thermal Sunyaev-Zel'dovich (tSZ) signal at the BOSS DR11 catalog positions. Our results were broadly consistent with those obtained from the kSZ signal. In the future, the tSZ signal may provide a valuable probe of cluster optical depths, enabling the extraction of velocities from the kSZ sourced mean pairwise momenta. New CMB maps from three seasons of ACTPol observations with multi-frequency

coverage overlap with nearly four times as many DR11 sources and promise to improve statistics and systematics for SZ measurements. With these and other upcoming data, the pairwise kSZ signal is poised to become a powerful new cosmological tool, able to probe large physical scales to inform neutrino physics and test models of modified gravity and dark energy.
Author(s): Eve Marie Vavagiakis[1], Francesco De Bernardis[1], Simone Aiola[2], Nicholas Battaglia[2], Michael D. Niemack[1]
Institution(s): *1. Cornell University, 2. Princeton University*
Contributing team(s): ACTPol Collaboration

310.05 – A Thermote, a Novel Thermal Element Simplifying the Finding of a Medium's Entropy Emerges as a Sensible Dark Matter Candidate from Primordial Black Holes with a Mass in Range of Axion's, a Leading Candidate

Black holes acting as dark matter have been predicted, e.g., via a duality theory in (Feria 2011, Proc. IEEE Int'l Conf. on SMC, Alaska, USA) and via observations in (Kashlinsky 2016, AJL). Here a thermote, a novel thermal element simplifying the finding of a medium's entropy, emerges as a dark matter candidate from primordial black holes with a mass in range of axion's, a leading candidate. The thermote energy, e_T, is defined as the average thermal energy contributed to a particle's motion by the medium's degrees of freedom (DoF) and is thus given by $e_T=N_{DoF}k_BT/2$ where N_{DoF} is the DoF number (e.g., $N_{DoF}=2$ for a black-hole since only in its event-horizon particle motions can occur) and $k_BT/2$ is the thermal energy contributed by each degree of freedom (k_B is the Boltzmann constant and T is temperature). The entropy S of a spherical homogeneous medium is then simply stated as $S=(k_B/2)E/e_T$ where $E=Mc^2$ is the medium's rest-energy, with M its point-mass and c the speed of light, and $e_T=N_{DoF}k_BT/2$ is the thermote's *kinetic-energy*. This simple equation naturally surfaced from a rest/kinetic or retention/motion mass-energy duality theory where, e.g., black-holes and vacuums form together such a duality with black holes offering the least resistance to mass-energy rest, or retention, and vacuums offering the least resistance to mass-energy kinetics, or motions. In turn, this duality theory has roots in the universal cybernetics duality principle (UCDP) stating "synergistic physical and mathematical dualities arise in efficient system designs" (Feria 2014, http://dx.doi.org/10.1117/2.1201407.005429, SPIE Newsroom). Our thermote based entropy finding method is applicable to spherical homogeneous mediums such as black-holes, photon-gases, and flexible-phase (Feria 2016, Proc. IEEE Int'l Conf. on Smart Cloud, Columbia University, NY, USA), where the thermote of a primordial black hole, with $N_{DoF}=2$ and a CMB radiation temperature of $T=2.725$ kelvin, emerges as a sensible dark matter candidade with a mass of 235.14 μeV which is within the predicted range of 50 μeV to 1,500 μeV for the axion after inflation (Borsanyi, *et al.* 2016, Nature, <ahref="http://dx.doi.org/10.1038/nature20115">http://dx.doi.org/10.1038/nature20115).
Author(s): Erlan H Feria[1]
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310.06 – Can LIGO Directly Detect the Scalar Field Dark Energy of 5D Gravity?

The observed acceleration of the present universe is commonly attributed to the existence of dark energy as a dominant component throughout the universe. A direct detection of dark energy has become one of the most important issues in the modern astrophysics and cosmology. Two widely accepted candidates of the dark energy are the cosmological constant Λ and the quintessence. Unlike the cosmological constant, the quintessence is a scalar field Φ that varies throughout spacetime, and has been modelled in various ways such as the four-dimensional (4D) Brans-Dicke scalar-tensor theory of gravitation and the five-dimensional (5D) Kaluza-Klein scalar-vector-tensor theory of gravitation. The scalar field of 5D gravity was shown to be capable of polarizing the space or vacuum and thus can extend the optical length of the path of a laser beam that passes through the polarized space or vacuum. Recently, the author, in terms of his 5D fully covariant Kaluza-Klein scalar-vector-tensor theory of gravitation, has quantitatively related the dielectric constant of the polarized vacuum (and thus the optical length of the path in the polarized vacuum) to the charge-mass ratio of a charged object. This study further demonstrates that the vacuum polarization by the scalar field dark energy of 5D gravity, when the object is highly charged, can be significant enough for the extremely accurate LIGO, which has recently detected first ever the gravitational waves from the binary black hole merger, to directly detect. It is shown that a some-thousand-kilogram sphere electrically charged to tens of kilovolts can polarize the vacuum by its scalar field dark energy and thus extend the optical path length of a laser beam that travels through one LIGO arm with some hundred reflections by approximately 10^{-18} m, which is one-order higher than that to be detected by the LIGO detectors. Therefore, being added a highly charged sphere into the experimental setup, LIGO may directly discover the scalar field dark energy of 5D gravity. Details on this new approach and experiment for detecting the scalar field dark energy of 5D gravity will be presented. This work was partially supported by NSF/REU (Grant #: PHY-1559870) at Alabama A & M University.
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311 – Plenary Talk: On the Explosion Geometry of Red Supergiant Stars, Doug Leonard (San Diego State University)

311.01 – On the Explosion Geometry of Red Supergiant Stars

We know that it happens, but we don't know how Nature does it. Roughly once per second in the observable universe, a red supergiant's inner core implodes under its own weight and then explodes as a supernova, announcing its demise with an optical display that for months rivals the combined brilliance of all of the other stars in its parent galaxy. And yet we must acknowledge basic ignorance: The physical process that successfully turns implosion into explosion still eludes us. Conventional wisdom posited a spherically symmetric explosion mechanism -- one that expels the massive star's envelope equally in all directions -- but both theoretical and observational discoveries have upended this Platonic ideal. In this talk I will provide a ``status report'' on our understanding of core-collapse supernova explosion geometry, with a particular focus on the unique ability of polarization measurements to reveal the early-time shape of the expanding, but unresolvable, photospheres of extragalactic supernovae.

Author(s): Douglas C. Leonard[1]
Institution(s): *1. San Diego State University*
Contributing team(s): The Supernova Spectropolarimetry Project (SNSPOL)

312 – AAS Members' Meeting

313 – AGN, QSO, and Blazars Poster Session

313.01 – Searching for Robust Accretion Rate Diagnostics in Distant Quasars

Estimates of quasar black-hole mass and accretion rate are often poorly constrained beyond a redshift of 0.8, and are considerably more difficult to obtain at the highest accessible redshifts. We address this challenge by investigating key multiwavelength spectroscopic properties of a carefully selected sample of Sloan Digital Sky Survey quasars at $0 < z < 3.6$ that do not have broad absorption lines and are not radio loud. This sample is further limited to sources that have high-quality data in the hard-X-ray, C IV, and Hβ spectral bands. We search for correlations between the hard-X-ray spectral slope and other potential accretion-rate diagnostics, such as the optical-X-ray spectral slope, emission line equivalent widths, and velocity shifts. The ultimate goal is to identify one of these observable properties, or a combination thereof, that would provide a robust and practical diagnostic of quasars' accretion rates, particularly in the early universe.

Author(s): Andrea Marlar[2], Ohad Shemmer[2], Michael S. Brotherton[3], Gordon T. Richards[1]
Institution(s): *1. Drexel University, 2. University of North Texas, 3. University of Wyoming*

313.02 – Testing Accretion Disk Wind Models of Broad Absorption Line Quasars with SDSS Spectra

We present an investigation of a large sample of broad absorption line (BAL) quasars (QSO) from the Sloan Digital Sky Survey (SDSS) Data Release 5 (DR5). Properties of the BALs, such as absorption equivalent width, outflow velocities, and depth of BAL, are obtained from analysis by Gibson et al. We perform correlation analysis on these data to test the predictions made by the radiation driven, accretion disk streamline model of Murray and Chiang. We find the CIV BAL maximum velocity and the continuum luminosity are correlated, consistent with radiation driven models. The mean minimum velocity of CIV is lower in low ionization BALs (LoBALs), than highly ionized BALs (HiBALS), suggesting an orientation effect consistent with the Murray and Chiang model. Finally, we find that HiBALs greatly outnumber LoBALs in the general BAL population, supporting prediction of the Murray and Chiang model that HiBALs have a greater global covering factor than LoBALs.

Author(s): Sean Lindgren[1], Jack Gabel[1]
Institution(s): *1. Creighton University*

313.03 – Long-term Variability Study of the Blazar B2 1215+30 at Gamma-Ray Energies

TeV extragalactic sources are predominantly blazars, a sub-type of active galactic nuclei (AGN), believed to be powered by central supermassive black holes, with relativistic jets pointing in Earth's general line of sight. B2 1215+30 is a BL Lac type of AGN, characterized by rapid and large-amplitude flux variability. The source was first detected at TeV energies by the MAGIC atmospheric Cherenkov telescope, and observed by VERITAS through the years 2009-2016. In 2014 February, VERITAS detected a luminous and isolated gamma-ray flare corresponding to 2.4 times the Crab Nebula's flux. Flares were also detected recently in 2015 and 2016. The observed variability at the highest energies in blazars offers clues to the physics of the blazar jet and constrains the size and location of the emission region in the jets. We will present here a long-term TeV study of the gamma-ray blazar B2 1215+30, using both VERITAS and Fermi-LAT gamma-ray data, and examine its flux variability in an attempt to understand the physical processes responsible for gamma-ray flares.

Author(s): Giuliana Noto[1], Janeth Valverde[2], Deirdre Horan[2], Reshmi Mukherjee[1]
Institution(s): *1. Barnard College, Columbia University, 2. École Polytechnique, LLR*
Contributing team(s): VERITAS collaboration, Fermi-LAT collaboration

313.04 – 2MASS J00423991+3017515: An Interacting Oddball or a Recoiling AGN?

We present deep, multiband Hubble imaging and two epochs of optical spectroscopic monitoring of a peculiar nearby (z=0.14) AGN, 2MASS J00423991+3017515. The host galaxy containing the AGN is morphologically disturbed and interacting with an unmerged companion galaxy, suggesting it has had a rich merger history. The AGN itself is spatially displaced from the apparent center of its host galaxy and the symmetric broad Hα and Hβ lines are consistently blueshifted from the narrow line emission and host galaxy absorption by Δv = 1530 km/s. The investigation is ongoing, but we put forward two hypotheses to explain the odd features of this system. First, the abnormalities could be due to separate, independent causes. Projection effects from the interaction of the two galaxies could give the appearance of a spatial offset, while complex wind dynamics from the AGN accretion disk could give rise to the kinematic shift in the broad line emission. Second, this could be a recoiling AGN. This system fits the template of an accreting supermassive black hole (SMBH) that has recently received a “kick” from the asymmetric emission of gravitational waves (GWs) following the merger of two progenitor SMBHs. SMBH mergers are a likely end-product of hierarchical structure formation and are the supermassive cousins of the stellar-mass BH mergers observed with LIGO in the GW150914 and GW151226 events. However, a SMBH merger has yet to be unambiguously detected. If confirmed as a recoiling AGN, 2MASS J00423991+3017515 will provide the first evidence of this growth pathway acting in the SMBH regime.

Author(s): J. Drew Hogg[1], Laura Blecha[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland*

313.05 – A Search for Optical/Infrared “Orphan Flares” in the SMARTS Sample of Fermi-Bright Blazars

Using simultaneous, multiwavelength observations of Fermi-bright blazars from the Small and Moderate Aperture Research Telescope System (SMARTS) 1.3m+ANDICam and Fermi Gamma-Ray Space Telescope+LAT, we construct optical/near-infrared (OIR) and gamma-ray light curves to identify OIR flares with no accompanying gamma-ray counterparts, i.e. “orphan flares.” An OIR orphan flare was first reported in PKS 0208-512 (Chatterjee et al. 2013), and thought to be due to either 1) a change in the magnetic field without a change in particle number or Doppler factor, or 2) an outburst located closer to the black hole with a smaller bulk Lorentz factor and less Compton upscattering. We extend the Chatterjee et al. analysis to include 35 of the 105 Fermi-bright, SMARTS-monitored blazars, report on the preliminary results of this study and attempt to empirically distinguish between these two physical mechanisms.

Author(s): John Calven Hood[1], Jedidah Isler[2], Kelly Holley-Bockelmann[2]
Institution(s): *1. Fisk University, 2. Vanderbilt University*

313.06 – Hypercat - Hypercube of Clumpy AGN Tori

Dusty tori surrounding the central engines of Active Galactic Nuclei (AGN) are required by the Unification Paradigm, and are supported by many observations, e.g. variable nuclear absorber (sometimes Compton-thick) in X-rays, reverberation mapping in optical/UV, hot dust emission and SED shapes in NIR/MIR, molecular and cool-dust tori observed with ALMA in sub-mm.

While models of AGN torus SEDs have been developed and utilized for a long time, the study of the resolved emission morphology (brightness maps) has so far been under-appreciated, presumably because resolved observations of the central parsec in AGN are only possible very recently. Currently, only NIR+MIR interferometry is capable of resolving the nuclear dust emission (but not of producing images, until MATISSE comes online). Furthermore, MIR interferometry has delivered also puzzling results, e.g. that in some resolved sources the light emanates preferentially from polar directions above the "torus" system, and not from the equatorial plane, where most of the dust is located.

We are preparing the release of a panchromatic, fully interpolable hypercube of brightness maps and projected dust images for a large number of CLUMPY torus models (Nenkova+2008), that will help facilitate studies of resolved AGN emission and dust morphologies. Together with the cube we will release a comprehensive set of open-source tools (Python) that will enable researches to work efficiently with this large hypercube:

* easy sub-cube selection + memory-mapping (mitigating the too-big-for-RAM problem)
* multi-dim image interpolation (get an image at any wavelength & model parameter combination)
* simulation of observations with telescopes (compute/provide + apply a PSF) and interferometers (get visibilities)
* analyze images with respect to the power contained at all scales and orientations (via 2D steerable wavelets), addressing the seemingly puzzling results mentioned above

A series of papers is in preparation, aiming at solving the puzzles, and at making predictions about the resolvability of all nearby AGN tori with any combination of current and future instruments (e.g. VLTI+MATISSE, TMT+MICHI, GMT, ELT, JWST, ALMA).

Author(s): Robert Nikutta[2], Enrique Lopez-Rodriguez[3], Kohei Ichikawa[1], Nancy Levenson[4], Christopher C. Packham[5]
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Observatory, 3. SOFIA, 4. Space Telescope Science Institute, 5. University of Texas at San Antonio

313.07 – The effect of bar-driven gas inflow on the AGN triggering in SDSS disc galaxies

We explore the role of bars in AGN activities using a volume-limited face-on disc galaxy sample with M_r<-19.5 and 0.02<z<0.055 selected from SDSS DR7. In this study, we investigate how the fraction of galaxies having strong bar is related to the amount of cold gas at galactic center (~1kpc scale) required for triggering AGN activity. To understand how directly the bar presence is related to triggering AGN activity, we measure a relative probability defined as the ratio of the probability of AGN triggering in barred galaxies to the probability of the AGN triggering in a comparison, non-barred galaxies, for fixed central SFR (central gas fuel) and velocity dispersion of galaxies (black hole mass). We find that bars are one of the mechanisms that trigger AGN, and the effect is pronounced in less massive and lasts even in galaxies with little central gas. We also suggest a concentrated bulge as a morphology that contributes to the AGN triggering although the effect is not as great as bars.

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Institution(s): *1. Kyung Hee University*

314 – Cosmology Poster Session

314.01 – Anisotropic Galaxy-Galaxy Lensing in the Illustris-1 Simulation

In Cold Dark Matter universes, the dark matter halos of galaxies are expected to be triaxial, leading to a surface mass density that is not circularly symmetric. In principle, this "flattening" of the dark matter halos of galaxies should be observable as an anisotropy in the weak galaxy-galaxy lensing signal. The degree to which the weak lensing signal is observed to be anisotropic, however, will depend strongly on the degree to which mass (i.e., the dark matter) is aligned with light in the lensing galaxies. That is, the anisotropy will be maximized when the major axis of the projected mass distribution is well aligned with the projected light distribution of the lens galaxies. Observational studies of anisotropic galaxy-galaxy lensing have found an anisotropic weak lensing signal around massive, red galaxies. Detecting the signal around blue, disky galaxies has, however, been more elusive. A possible explanation for this is that mass and light are well aligned within red galaxies and poorly aligned within blue galaxies (an explanation that is supported by studies of the locations of satellites of large, relatively isolated galaxies). Here we compute the weak lensing signal of isolated central galaxies in the Illustris-1 simulation. We compute the anisotropy of the weak lensing signal using two definitions of the geometry: [1] the major axis of the projected dark matter mass distribution and [2] the major axis of the projected stellar mass. On projected scales less than 15% of the virial radius, an anisotropy of order 10% is found for both definitions of the geometry. On larger scales, the anisotropy computed relative to the major axis of the projected light distribution is less than the anisotropy computed relative to the major axis of the projected dark matter. On projected scales of order the virial radius, the anisotropy obtained when using the major axis of the light is an order of magnitude less than the anisotropy obtained when using the major axis of the dark matter. The suppression of the anisotropy when using the major axis of the light to define the geometry is indicative of a significant misalignment of mass and light in the Illustris-1 galaxies at large physical radii.

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314.02 – The Suppression of Star Formation in Low-Mass Galaxies Caused by the Reionization of their Local Patch

The first stars and galaxies released enough ionizing radiation into the intergalactic medium (IGM) to ionize almost all the hydrogen atoms there by redshift z ~ 6. This process was "patchy" --- ionized zones grew in size over time until they overlapped to finish reionization. The photoheating associated with reionization caused a negative feedback on the galactic sources of reionization that suppressed star formation in low-mass galactic halos, especially those below 10^9 $M_\odot$. To establish the causal connection between reionization and this suppression, we analyze the results of CoDa ("Cosmic Dawn"), the first fully-coupled radiation-hydrodynamical simulation of reionization and galaxy formation in the Local Universe, in a volume large enough to model reionization globally but with enough resolving power to follow all the atomic-cooling galactic halos in that volume. A 90 Mpc box was simulated from a constrained realization of primordial fluctuations, chosen to reproduce present-day features of the Local Group, including the Milky Way and M31, and the local universe beyond, including the Virgo cluster, with 4096^3 N-body particles for the dark matter and 4096^3 cells for the atomic gas and ionizing radiation. We use these results to show that the star formation rate in haloes below 10^9 $M_\odot$ in different patches of the universe declined when each patch was reionized. Star formation in much more massive haloes continued, however. As a result, the earliest patches to develop structure and reionize ultimately produced more stars than they needed to reionize themselves, exporting their starlight to help reionize the regions that developed structure late.

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314.03 – Distinguishing CDM dwarfs from SIDM dwarfs in baryonic simulations

Dwarf galaxies in the nearby Universe are the most dark-matter-dominated systems known. They are therefore natural probes of the nature of dark matter, which remains unknown. Our collaboration has performed several high-resolution cosmological zoom-in simulations of isolated dwarf galaxies. We simulate each galaxy in standard cold dark matter (ΛCDM) as well as self-interacting dark matter (SIDM, with a cross section of $\sigma/m \sim 1\ cm^2/g$), both with and without baryons, in order to identify distinguishing characteristics between the two. The simulations are run using GIZMO, a meshless-finite-mass hydrodynamical code, and are part of the Feedback in Realistic Environments (FIRE) project. By analyzing both the global properties and inner structure of the dwarfs in varying dark matter prescriptions, we provide a side-by-side comparison of isolated, dark-matter-dominated galaxies at the mass scale where differences in the two models of dark matter are thought to be the most obvious. We find that the edge of classical dwarfs and ultra-faint dwarfs (at stellar masses of $\sim 10^5$ solar masses) provides the clearest window for distinguishing between the two theories. At these low masses, our SIDM galaxies have a cored inner density profile, while their CDM counterparts have "cuspy" centers. The SIDM versions of each galaxy also have measurably lower stellar velocity dispersions than their CDM counterparts. Future observations of ultra faint dwarfs with JWST and 30-m telescopes will be able to discern whether such alternate theories of dark matter are viable.

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314.05 – Large Local Void, Supernovae Type Ia, and the Kinematic Sunyaev-Zel'dovich Effect in a Lambda-LTB Model

There is substantial and growing observational evidence from the normalized luminosity density in the near-infrared that the local universe may be under-dense on scales of several hundred Megaparsecs. Our objective is to test whether a void described by a parameterization of the observational data is compatible with the latest data on supernovae type Ia and the linear kinematic Sunyaev-Zel'dovich (kSZ) effect. Our study is based on the large local void radial profile observed by Keenan, Barger, and Cowie (KBC) and a theoretical void description based on the Lemaître-Tolman-Bondi model with a nonzero cosmological constant (Lambda-LTB). We find consistency with the measured luminosity distance-redshift relation on radial scales relevant to the KBC void through a comparison with low-redshift supernovae type Ia from the `Supercal' dataset over the redshift range $0.01 < z < 0.10$. We also find that previous linear kSZ constraints, as well as new ones from the South Pole Telescope, are fully compatible with the existence of the KBC void.

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314.06 – Measurement of the Shape of the Optical-IR Spectrum of Prompt Emission from Gamma-Ray Bursts

While the afterglow phase of gamma-ray bursts (GRBs) has been extensively measured, detections of prompt emission (i.e. during bright X-gamma emission) are more limited. Some prompt optical measurements are regularly made, but these are typically in a single wide band, with limited time resolution, and no measurement of spectral shape. Some models predict a synchrotron self-absorption spectral break somewhere in the IR-optical region. Measurement of the absorption frequency would give extensive information on each burst, including the electron Lorentz factor, the radius of emission, and more (Shen & Zhang 2008). Thus far the best prompt observations have been explained invoking a variety of models, but often with a non-unique interpretation. To understand this apparently heterogeneous behavior, and to reduce the number of possible models, it is critical to add data on the optical - IR spectral shape.

Long GRB prompt X-gamma emission typically lasts ~40-80 s. The Swift BAT instrument rapidly measures GRB positions to within a few arc minutes and communicates them via the internet within a few seconds. We have measured the time for a fast-moving D=700 mm telescope to point and settle to be less than 9 s anywhere on the observable sky. Therefore, the majority of prompt optical-IR emission can be measured responding to BAT positions with this telescope. In this presentation, we describe our observing and science programs, and give our design for the Burst Simultaneous Three-channel Instrument (BSTI), which uses dichroics to send eparate bands to 3 cameras. Two EMCCD cameras, give high-time resolution in B and V; a third camera with a HgCdTe sensor covers H band, allowing us to study extinguished bursts. For a total exposure time of 10 s, we find a 5 sigma sensitivity of 21.3 and 20.3 mag in B and R for 1" seeing and Kitt Peak sky brightness, much fainter than typical previous prompt detections. We estimate 5 sigma H-band sensitivity for an IR optimized telescope to be ~16.9 mag in 20 s. With three channels broadly separated in wavelength, two separate slopes would be measured, or if present between our bands, the absorption frequency would be determined, a brand-new window into GRB physics.

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Contributing team(s): Energetic Cosmos Laboratory

314.07 – New LIGO Constraints on Bose-Einstein-Condensed Scalar Field Dark Matter and the Stochastic Gravitational-Wave Background from Inflation

We consider an alternative to WIMP cold dark matter (CDM), ultralight bosonic dark matter ($m \gtrsim 10^{-22}$eV) described by a complex scalar field (SFDM) with global U(1) symmetry, for which the comoving particle number density is conserved after particle production during standard reheating. We allow for a repulsive self-interaction. In a ΛSFDM universe, SFDM starts relativistic, evolving from stiff (w=1) to radiationlike (w=1/3), before becoming nonrelativistic at late times (w=0). Thus, before the familiar radiation-dominated era, there is an earlier era of stiff-SFDM-domination, during which the expansion rate is *higher* than in ΛCDM. SFDM particle mass m and coupling strength λ, of a quartic self-interaction, are therefore constrained by cosmological observables, particularly N_{eff}, the effective number of neutrino species during BBN, and z_{eq}, the redshift of matter-radiation equality. Furthermore, since the stochastic gravitational-wave background (SGWB) from inflation is amplified during the stiff era, it can contribute a radiationlike component large enough to affect these observables by further boosting the expansion rate. Remarkably, this same amplification makes detection of the SGWB possible at high frequencies by current laser interferometer experiments, e.g., aLIGO/Virgo and LISA. For SFDM particle parameters that satisfy these cosmological constraints, the amplified SGWB is detectable by LIGO for a broad range of reheat temperatures T_{reheat}, for values of tensor-to-scalar ratio r currently allowed by CMB polarization measurements. The SGWB is maximally detectable if modes that reentered the horizon when reheating ended have frequencies today in the LIGO sensitive band. For r=0.01, if SFDM parameters are chosen which marginally satisfy the above constraints, the maximally detectable model for $(\lambda/(mc^2)^2, m)=(10^{-18}\text{eV}^{-1}\text{cm}^3, 8\times10^{-20}\text{eV})$ corresponds to $T_{reheat}\approx10^4$GeV, for which we predict an aLIGO O1 run detection with SNR~10. Upper limits on the SGWB reported by aLIGO O1 are used to place a new kind of cosmological constraint on SFDM. A wider range of SFDM parameters and T_{reheat} should be accessible to aLIGO/Virgo O5. For r=0.01 and $\lambda/(mc^2)^2=10^{-18}\text{eV}^{-1}\text{cm}^3$, 3σ detection is predicted for $600\leq T_{reheat}(\text{GeV})\leq10^7$ by O5.

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314.08 – Lack of small-scale clustering in 21-cm intensity maps crossed with 2dF galaxy densities at z ~ 0.08

I report results from 21-cm intensity maps acquired from the Parkes radio telescope and cross-correlated with galaxy maps from the 2dF galaxy survey. The data span the redshift range 0.057<z<0.098 and cover approximately 1,500 square degrees over two long fields. The cross-power spectrum exhibits a dip in power at small scales, around k~1.0 hMpc^-1, compared to the 2dF auto-power spectrum and the theoretical dark matter power spectrum. This indicates either a lack of clustering of neutral hydrogen (HI) at small scales or a small correlation coefficient between optical galaxies and HI, or some combination of the two. A lack of small scale HI clustering would be qualitatively similar to measurements of HI-selected galaxy clustering from the HIPASS and ALFALFA surveys at slightly lower redshifts.

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314.09 – A VLT/FORS2 Narrowband Imaging Search for MgII Emission Around z~0.7 Galaxies

Galactic-scale outflows are thought to be the primary mechanism in the removal of cool gas in star-forming galaxies. Presently, the mass and energy of these flows remain poorly constrained. One way to better constrain these parameters is to measure the spatial extent of the outflow; however, measuring the spatial extent of such outflows via spectral methods has been traditionally very difficult due to the faintness of emission lines tracing outflowing material. We present VLT/FORS2 narrowband imaging of 5 star forming galaxies at redshift z=0.67-0.69 in the GOODS-S field as part of an effort to spatially resolve large-scale outflows traced by MgII emission. Previous spectra of this sample have already revealed winds traced by MgII absorption. At our sample redshift, the MgII emission lines fall exactly within the FORS2 HeII+47 and HeII/3000+48 interference filters. The total integration time of 10 hrs obtained in each filter permits the analysis of the flow surface brightness and extent on scales over which MgII is typically detected in absorption (i.e, projected distances > 100 kpc). Such measurements can provide stronger constraints on the mass and energy of

feedback, helping to advance our understanding of the processes regulating galaxy evolution up to z=1.

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315 – Stars and Stellar Topics Poster Session

315.01 – Probing the Long Timescale Evolution of Magnetic Activity of Ultracool Dwarfs

The chromospheric variability, as measured by H-alpha emission, of ultracool dwarfs (M7-L3) is still not completely understood. Using spectra from the Sloan Digital Sky Survey (SDSS), we are in the process of measuring equivalent widths of the H-alpha emission lines of ultracool dwarfs over multi-year timescales. More specifically, we are utilizing spectra from Data Release 7, composed of data from 2000-2008, and the Few Epoch Spectroscopy (FES) component of the Time Domain Spectroscopic Survey (TDSS), which is composed of data from 2014-2018. We have 2-3 spectra for 1000 objects and will obtain H-alpha equivalent width measurements over time spans of 6-18 years. By studying the chromospheres of ultracool dwarfs on these timescales, we can make comparisons to the solar magnetic cycle and try to understand the process causing their H-alpha variability. Additionally, we can investigate any relationship between variability and stellar age by combining our measurements with tracers like galactic height and UVW kinematics. We will present preliminary results of this work.

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315.02 – Individual Dynamical Masses of Ultracool Dwarfs

We present the full results of our decade-long astrometric monitoring programs targeting 31 ultracool binaries with component spectral types M7–T5. Joint analysis of resolved imaging from Keck and *HST* and unresolved astrometry from CFHT/WIRCam yields parallactic distances for all systems, robust orbit determinations for 23 systems, and photocenter orbits for 19 systems. As a result, we measure 38 precise individual masses spanning 30–115 M_{Jup}. We determine a model-independent substellar boundary that is ≈70 M_{Jup} in mass (≈L4 in spectral type), and we validate BHAC15 evolutionary model predictions for the lithium-depletion boundary (60 M_{Jup} at field ages). Assuming each binary is coeval, we test models of the substellar mass–luminosity relation and find in the L/T transition only SM08 "hybrid" models accounting for cloud clearing match our data. Our masses enable a novel direct determination of the age distribution of field brown dwarfs spanning L4–T5 and 30–70 M_{Jup}. We determine a median age of 1.3 Gyr, and our population synthesis modeling indicates our sample is consistent with a constant star formation history modulated by dynamical heating in the Galactic disk. Overall, this work represents a major advance in the empirical view of very low-mass stars and brown dwarfs.

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315.03 – A Study of the Multiple Populations in M10

We present an analysis of CN and CH band strengths which allow the identification of multiple populations in red giant stars in the globular cluster M10. Our measurements come from low-resolution spectroscopy obtained for ~140 red and asymptotic giant branch stars over two observation runs using Hydra on the WIYN 3.5m telescope. We sort the stars into nitrogen normal and enhanced populations based on the distribution of CN band strength as a function of magnitude. Once the stars are sorted into first and second generation (CN normal and enhanced, respectively), we compare this analysis to other ways of determining multiple stellar populations such as with the light elements Na and O and photometric indicators, particularly the UV photometry from the Hubble Space Telescope. C and N abundances are determined by matching observed CN and CH band measurements with those produced by synthetic spectra created with the Synthetic Spectrum Generator (SSG). The large sample size also allows us to study characteristics like radial distribution, and evolutionary effects such as the depletion of carbon (and subsequent nitrogen enrichment) as a star climbs the red giant branch. We find a rate of carbon depletion as a function of time for both populations in M10 and compare our result to M13, a cluster similar in metallicity.

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315.04 – Field Red Horizontal Branch Star Chemical Compositions from High Resolution Infrared Spectra

We have observed three field red horizontal branch stars with the Immersion Grating Infrared Spectrograph (IGRINS). The high resolution (R~45000) high signal-to-noise (S/N > 200) spectra obtained with IGRINS cover the complete H-band (1.50-1.80 micron) and K-band (1.90-2.45 micron). We analyzed hundreds of lines of the ubiquitous OH, CN, and CO molecular bands, and found more than 80 lines of atomic species that were useful for abundance work. A combination of good laboratory transition probabilities (when available) and ones derived from reverse solar analyses were employed.

Our transition data were checked through studies of the Arcturus Atlas spectrum. We derived abundances from synthetic spectra instead of from equivalent widths. With IGRINS data we were able to extract metallicities and abundance ratios for more than 20 elements, including several not detectable or poorly represented in optical wavelength regions. Our abundances from IGRINS spectra are in excellent accord with those derived from optical spectrum studies. These results are directly applicable to calibrations of results from lower-resolution and/or S/N infrared spectral surveys. IGRINS observations will give high reolution spectroscopic access to heavily obscured normal red giants and other cool stars with unusual element mixes.

This work used the Immersion Grating Infrared Spectrograph (IGRINS) that was developed under a collaboration between the University of Texas at Austin and the Korea Astronomy and Space Science Institute (KASI) with the financial support of the US National Science Foundation (NSF; grant AST-1229522), of the University of Texas at Austin, and of the Korean GMT Project of KASI. Our project also has been supported by NSF grants AST~1211585 and AST~1616040, by the University of Texas Rex G. Baker, Jr. Centennial Research Endowment, and by The Scientific and Technological Research Council of Turkey (TUBITAK, project No. 112T929).

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315.05 – A Near-Infrared Surface Compositional Analysis of Blue Straggler Stars in Open Cluster M67

Blue straggler stars (BSSs) are stars whose evolutions have been directly impacted by binary system interactions. By obtaining additional mass from a companion, BSSs are able to live prolonged lives on the main sequence. BSSs bring confusions to studies that rely on a standard stellar evolutionary track when modeling stellar populations, since the presence of BSSs can make a population appear younger than it actually is. It is important to have a better understanding of the mechanisms that drive BSS formation so that BSSs may be correctly accounted for in future studies.

Blue stagglers in clusters primarily form in one of two ways; either from a close binary system in which one star accretes mass from its companion star or from a hierarchical trinary system in which a close inner binary merges as a result of perturbations from a farther-orbiting third star. In order to investigate the nature of this mass transfer, We obtained IGRINS H-band high resolution spectra of 6 BSSs and 12 red giant stars in open cluster M67. Using a grid of synthetic spectra obtained from the line analysis code MOOG, we identified and fit abundances for absorption lines of iron, silicon, and carbon. Depending on the evolutionary stage of the donor star, the abundance of carbon in the resulting BSS can be affected by mixing during the mass transfer. By analyzing the abundance of carbon in our targets, we find that [Fe/H] ~= 0 and [C/H] ~= 0. We see no evidence of depletion of carbon from RGB-phase mass transfer or enhancement of carbon from AGB-phase mass transfer, implying that the mass transfer occured earlier in the donar star's evolution.

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315.06 – Exploring Photometric Methods for Identifying Emission-Line B-Type Stars

Emission-line B-type stars, or Be stars, are a mysterious class of stars defined by their unique behavior: These stars eject material from their surfaces, forming a disc of gas that surrounds them. Furthermore, the gaseous disc is not necessarily a permanent feature of its host star. Some Be stars' discs vary in structure over time, and may even disappear only to be regenerated later. Other Be stars may never show appreciable changes in the natures of their discs once they have been formed. The disc's existence causes the appearance of characteristic emission lines in Be stars' spectra, making spectroscopy the traditional method for identifying Be stars. However, spectroscopy is an inefficient and time-consuming method of finding Be stars, because it allows for only a single star to be observed in each exposure, and each star may require multiple exposures for durations of many minutes. Photometry, on the other hand, can be used to observe many stars simultaneously, but at the cost of the greater detail afforded by spectroscopy. While photometry has been used to identify Be stars, its success has been limited. In this work, we present a novel photometric technique that enables efficient identification of Be stars.
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315.07 – Sonora: A New Generation Model Atmosphere Grid for Brown

Dwarfs and Young Extrasolar Giant Planets

Brown dwarf and giant planet atmospheric structure and composition has been studied both by forward models and, increasingly so, by retrieval methods. While indisputably informative, retrieval methods are of greatest value when judged in the context of grid model predictions. Meanwhile retrieval models can test the assumptions inherent in the forward modeling procedure.

In order to provide a new, systematic survey of brown dwarf atmospheric structure, emergent spectra, and evolution, we have constructed a new grid of brown dwarf model atmospheres. We ultimately aim for our grid to span substantial ranges of atmospheric metallilcity, C/O ratios, cloud properties, atmospheric mixing, and other parameters. Spectra predicted by our modeling grid can be compared to both observations and retrieval results to aid in the interpretation and planning of future telescopic observations.

We thus present Sonora, a new generation of substellar atmosphere models, appropriate for application to studies of L, T, and Y-type brown dwarfs and young extrasolar giant planets. The models describe the expected temperature-pressure profile and emergent spectra of an atmosphere in radiative-convective equilibrium for ranges of effective temperatures and gravities encompassing $200 \leq T_{\rm eff} \leq 2400$ K and $2.5 \leq \log g \leq 5.5$. In our poster we briefly describe our modeling methodology, enumerate various updates since our group's previous models, and present our initial tranche of models for cloudless, solar metallicity, and solar carbon-to-oxygen ratio, chemical equilibrium atmospheres. These models will be available online and will be updated as opacities and cloud modeling methods continue to improve.

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315.08 – Atmospheric Modeling and Retrieval of Cool Y Dwarfs

Brown dwarfs' near-infrared spectra contain a wealth of information which can reveal the physical and chemical processes that occur in their atmospheres. Using a recently developed atmospheric retrieval model, we are able to constrain various molecular abundances, along with photometric radius, gravity, cloud optical depths, and temperature profiles for a set of ultral-cool (T8-Y1) dwarfs observed with the Hubble Space Telescope Wide Field Camera 3. From these spectra, we are able to constrain the abundances of water, methane, ammonia, CO, CO_2, H_2S, and Na+K. Using the retrieved abundances of water and methane, we are able to determine the atmospheric carbon-to-oxygen ratio and metallicity for these objects. We also identify a continuing trend of alkali metal depletion towards cooler effective temperatures likely due to the formation of optically thin Na2S and KCl clouds.

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315.09 – High-Resolution Infrared Spectroscopic Observations of the Upper Scorpius Eclipsing Binary EPIC 203868608

EPIC 203868608 is a source in the ~10 Myr old Upper Scorpius OB association. Using K2 photometry and ground-based follow-up observations, David et al. (2016) found that it consists of two brown dwarfs with a tertiary object at a projected separation of ~20 AU; the former objects appear to be a double-lined eclipsing binary with a period of 4.5 days. This is one of only two known eclipsing SB2s where both components are below the hydrogen-burning limit. We present additional follow-up observations of this system from the IGRINS high-resolution near-infrared spectrograph at McDonald Observatory. Our measured radial velocities do not follow the orbital solution presented by David et al. (2016). Instead, our combined IGRINS plus literature radial velocity dataset appears to indicate a period significantly different than that of the eclipsing binary obvious from the K2 light curve. We will discuss possible scenarios to account for the conflicting observations of this system.

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315.10 – Determining Optimal Parameters for Brown Dwarf Spectral Extraction using the aXe Pipeline

This research seeks to find optimal extraction parameters for brown dwarf slitless spectra obtained using the Wide Field Camera 3 (WFC3), with the G141 grism on the Hubble Space Telescope. We have used the STScI aXe pipeline to extract spectral time series for three brown dwarf targets from HST program GO-13299 (PI: Radigan). These targets include two L/T transition dwarfs 2MASS-J16291840+033537 and SDSS-J075840.33+324723.4, and one L-dwarf 2MASS-J11263991-5003550. The parameters explored in this study include the spectral extraction width, the type of background subtraction, and the pixel weighting of the extraction. We also explore how target brightness effects the optimal reduction parameters. Scatter within the spectral time series are used to draw conclusions regarding the relative goodness of different sets of reduction parameters.

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315.11 – Using Hydrogen Recombination Masers to Study Disk and Wind Kinematics in MWC 349A

The kinematics of circumstellar disks and disk winds are poorly understood due to the difficulty of producing well resolved observational data. The bright hydrogen recombination-line maser emission originating from the circumstellar disk of MWC 349A offers a unique opportunity to study the disk at milli-arcsecond precision. Using high angular resolution observations of the maser emission from MWC 349A carried out by the SMA, we were able to produce and analyze rotation curves for the H26α, H30α, and H31α transitions. We found that maser features originating from the disk follow Keplerian motion. Furthermore, the H31α masers in the disk appear to form in a narrow annulus at a fixed radius from the star, consistent with previous studies of the H30α and H26α masers. Based on analysis of the rotation curves for the three maser transitions, we determined that maser transitions for lower quantum numbers occur in the inner and denser regions of the disk than the higher quantum transitions. Additionally, we derived the density distribution within the disk, which follows the relation $n_e \sim R^{-4.9 \pm 0.6}$. Finally, we found that a stellar mass of $M = 10 \pm 3\ M_\odot$ was most consistent with the kinematics of the maser features originating from the Keplerian disk.

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315.12 – SMA Continuum Survey of Circumstellar Disks in Serpens

The lifetime of disks surrounding pre-main-sequence stars is closely linked to planet formation and provides information on disk dispersal mechanisms and dissipation timescales. The potential for these optically thick, gas-rich disks to form planets is critically dependent on how much dust is available to be converted into terrestrial planets and rocky cores of giant planets. For this reason, an understanding of how dust mass varies with key properties such as stellar mass, age, and environment is critical for understanding planet formation. Millimeter wavelength observations, in which the dust emission is optically thin, are required to study the colder dust residing in the disk's outer regions and to measure disk dust masses. Hence, we have obtained SMA 1.3 mm continuum observations of 62 Class II sources with suspected circumstellar disks in the Serpens star-forming region (SFR). Relative to the well-studied Taurus SFR, Serpens allows us to probe the distribution of dust masses for disks in a much denser and more clustered environment. Only 13 disks were detected in the continuum with the SMA. We calculate the total dust masses of these disks and compare their masses to those of disks in Taurus, Lupus, and Upper Scorpius. We do not find evidence of diminished dust masses in Serpens disks relative to those in Taurus despite the fact that disks in denser clusters may be expected to contain less dust mass due to stronger and more frequent tidal interactions that can disrupt the outer regions of disks. However, considering the low detection fraction, we likely detected only bright continuum sources and a more sensitive survey of Serpens would help clarify these results.

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315.13 – Hubble Space Telescope measures relativistic deflection of background starlight by a nearby white dwarf

The deflection of images of background stars by curved space near the Sun during the 1919 total eclipse spectacularly confirmed Einstein's general theory of relativity. A century later, the superb angular resolution of the Hubble Space Telescope has enabled us to measure the deflection of a background star's position as a nearby white dwarf, Stein 2051B, passed in front of it. This allows us to determine the mass of a star using this technique of "astrometric microlensing" for the first time outside the solar system. Our measurement of the mass of Stein 2051 B—the sixth-nearest white dwarf—provides confirmation of the physics of degenerate matter, and lends support for white-dwarf evolutionary theory.

Author(s): Kailash C. Sahu[2], Jay Anderson[2], Stefano Casertano[2], Howard E. Bond[1], Pierre Bergeron[3], Edmund P. Nelan[2], Laurent Pueyo[2], Thomas M. Brown[2], Andrea Bellini[2], Zoltan G. Levay[2], Martin Dominik[5], Annalisa Calamida[2], Noé Kains[2], Josh Sokol[2], Mario Livio[4]
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315.14 – An asteroseismic differentiation of pulsating stars in the extremely low mass white dwarf regime

White dwarf stars have been observed to vary in a variety of ways, from the pulsations of classical hydrogen atmosphere white dwarfs (ZZ Cetis) to ellipsoidal variations in short-period post common envelope binaries. A recently discovered class of white dwarf, those with masses below 0.3 solar masses, have been discovered to pulsate in a low log-g extension of the ZZ Ceti instability strip (1000K < Teff < 8800K and 7 > log-g > 6). These are the pulsating extremely low mass white dwarfs (ELMVs), thought to form through mass transfer in binary systems, an evolutionary pathway which allows such low mass white dwarfs to exist. This region of parameter space is crowded, however, with thousands of poorly understood stars uncovered in recent Sloan Digital Sky Survey data releases 10 and 12. These are the sub–dwarf A stars (sdAs), named so for their hydrogen dominated spectra and sub-main sequence log-g's, which are largely either isolated ELMs, halo A stars, or subdwarfs with main sequence FGK companions. The overlap between ELMVs and sdAs makes it difficult to classify the ELMVs spectroscopically without first confirming their short-period binary nature with radial velocity (RV) measurements. Currently, nine pulsating stars are published in the ELMV parameter space, but only four exhibit RV variations, much less than one might expect due to random inclination orientation alone. Those without RV variation are considered connected to the poorly understood sdAs. With upgrades made to the Argos photometer at McDonald Observatory, we have enabled high-speed multi-color photometry and have begun to observe both the ELMVs, sdAs, and other pulsators within the ELM parameter space. Our goal is to asteroseismically differentiate ELMVs from other stellar variables by measuring color amplitude ratios and phase difference between filters. We present here the current results of our efforts.

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315.15 – Far-Infrared and Nebular Star-Formation Rate of Dusty Star Forming Galaxies from *Herschel, CANDELS* and *3D-HST* at z~1

We present a combined *Herschel*/PACS and SPIRE and HST/WFC3 observations of the five CANDELS fields, EGS, GOODS-N, GOODS-S, COSMOS and UDS, to study star-formation activity in dusty star-forming galaxies (DSFGs) at z~1. We use 3D-HST photometry and Grism spectroscopic redshifts to construct the Spectral Energy Distributions (SED) of galaxies in the near UV, optical and near infrared, along with IRAC measurements at 3.6-8 μm in the mid-infrared, and *Herschel* data at 250-500 μm in the far-infrared. The 3D-HST grism line measurements are used to estimate the star-formation rate from nebular emission. In particular, we compare the H-alpha measured SFRs (corrected for attenuation) to that of direct observations of the far-infrared from *Herschel*. We further look at the infrared excess in this sample of dusty star-forming galaxies (denoted by L_{IR}/L_{UV}) as a function of the UV slope. We find that the population of high-z DSFGs sit above the trend expected for normal star-forming galaxies. Additionally, we study the dependence of SFR on total dust attenuation and confirm a strong correlation between SFR(Ha) and the balmer decrement ($H\alpha/H\beta$).

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Contributing team(s): Herschel group: University of California Irvine. Dept. of Physics & Astronomy. Led by professor Asantha Cooray, Reed College Undergraduate Research Committee

315.16 – Follow up observationes of extremely metal-poor stars identified from SDSS and LAMOST

The most metal poor stars in milky way witnessed the early phases of formation of the Galaxy, and have chemical compositions that are close to the pristine mixture from Big Bang nucleosynthesis, polluted by one or very few supernovae. Here we present a program we are carrying out to search for and characterize new ultra metal-poor stars formed in the early Milky Way. Unfortunately, these stars are extremely rare. Despite significant eforts, only a handful of stars have been identified with a metallicity [Fe/H]< 5, and among those there is only one with [Fe/H]< 7. We have selected iron poor candidates from SDSS and LAMOST. Dozens of them have been observed with ISIS on the 4.2 m William Herschel Telescope. The most interesting objects have been confirmed with OSIRIS on 10.4m-GTC and HRS on 9.2 m HET. We present the results of our analysis with the FERRE code. In addition, we report the discovery of a new carbon rich ultra metal poor (CRUMP) dwarf star in the[Fe/H]~-5.0 regime and a huge carbon abundance [C/Fe]~+5.8. We will discuss the implications of this discovery on our knowledge of the Early Galaxy, and the formation of the first stars and supernovae.

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316 – Evolution of Galaxies Poster Session

316.01 – Modeling X-ray Emission of Galactic Winds

Despite galaxies being the main players on the cosmological scene, and our living inside of one, the processes of evolution which create these structures are still a mystery. Galactic winds are an important component of galaxy evolution and the mechanisms which drive these outflows have yet to be explained. We have incorporated x-ray production into a preexisting model of galactic outflows in order to generate predictions of x-ray luminosity to test current wind theories against observations. Specifically, the model is a representation of thermally driven winds. First, we incorporated the equations for x-ray luminosity into the wind model and tested its effects over a wide range of parameter space. We then created models to match the parameters of several cool galactic outflows previously studied. Finally, we searched the relevant literature for observations of these galaxies that we could use to compare with our predicted luminosities. Our models consistently predicted luminosities within a factor of two of the observed values. This led to the conclusion that if the hot and cool gas are coupled then thermal energy may play a role in the driving of these winds. Unraveling this mystery will be key to understanding galactic outflows and galactic evolution overall.

Author(s): Teague Tomesh[1], Ellen Gould Zweibel[1], Chad Bustard[1]
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316.02 – Super-massive binary black holes in galaxies. Dynamical models and observed structures in Arp 5, 87, 214, 240, and NGC 4027, 6946

On 14 Sept, 2015 The LIGO reported the first direct detection of gravitational waves and the first direct observation of a binary black hole. These observations demonstrate the existence of binary black holes in stellar systems predicted by Einstein in his general theory of relativity a century earlier.
A lot of violent and complicated phenomena take place on different scales in the Universe. Many of them may be caused by multiple centers of gravitational attraction: planetary rings, accretion discs of various scales, peculiar structures of single galaxies and interacting galaxies. In this work, we show that various features of celestial objects can be understood by assuming the existence of two dominant centers of gravity in stellar systems.
We study numerically the dynamical evolution of models with the central super-massive binary black holes and extended shells with numerous low-mass particles inside and around the orbits of binaries. These particles could be star clusters or gas and dust complexes. We consider several tens of thousands of initial conditions for the general three-body problem and compile them. We studied the dynamical evolution of all spherical shells together and separately. Our method permits us to study the individual trajectories of particles, their close double and triple approaches, and inspect the time-depending structures in the models. Multiple runs of the models allow us to classify the numerous strong triple interactions of the binary components with low-mass particles; frequently, the "gravitational slingshot" effect occurs in the center of systems. Such strong interactions of bodies are results in various structures with "dumb-bell" bars, close and open spirals, different types of flows, jets etc. These structures are often very similar the observed structures of galaxies.
We found some combinations of the initial conditions and model parameters that produce at some time similar structures as that found in the galaxies Arp 5, 87, 214, 240, and NGC 4027, 6946. Our Figures show results of such comparison and the past and future evolution of our models.

Author(s): Joanna P. Anosova[1]
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316.03 – Quasars Probing Quasars: The quasar pair catalog

The rare close projection of two quasars on the sky provides the opportunity to study the host galaxy environment of a foreground quasar in absorption against the Lyman-alpha emission of a background quasar. For over a decade the "Quasars probing quasars" series has utilized this technique to further the understanding of galaxy formation and evolution in the presence of a quasar at z>2, resolving scales as small as a galactic disc, where the UV ionizing flux from the quasar can exceed ~10^4 times the ambient UV background. This poster presents the public release of the quasar pair catalog utilized in these studies. In addition, the catalog also includes quasar pair members at z<2, gravitational lens candidates and quasars closely separated in redshift that are useful for small-scale clustering studies. We outline the key contributions made by this series over the last ten years, summarize the imaging and spectroscopic data used for target selection, discuss the target selection methodologies, describe the catalog content, and explore some avenues for future work. This poster was partially supported by NSF grants 1515404 and AST-1412981.

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316.04 – A Faint Flux-Limited Lyman Alpha Emitter Sample at z=0.3

We present a flux-limited sample of z=0.3 Lya emitters (LAEs) from Galaxy Evolution Explorer (GALEX) grism spectroscopic data. The published GALEX z=0.3 LAE sample is pre-selected from continuum-bright objects and thus is biased against high equivalent width (EW) objects. We remove this continuum pre-selection and compute the EW distribution and the luminosity function of the Lya emission line from our sample. We examine the evolution of these quantities from z = 0.3 to 2.2 and find that the EW distribution shows little evidence for evolution over this redshift range. As shown by previous studies, the Lya luminosity density from star-forming galaxies declines rapidly with declining redshift. However, we find that the decline in Lya luminosity density from z=2.2 to z=0.3 may simply mirror the decline seen in the Ha luminosity density from z=2.2 to z=0.4, implying little change in the volumetric Lya escape fraction. Finally, we show that the observed Lya luminosity density from AGNs is comparable to the observed Lya luminosity density from star-forming galaxies at z=0.3. We suggest that this significant contribution from AGNs to the total observed Lya luminosity density persists out to z=2.2.

Author(s): Isak Wold[2], Steven L. Finkelstein[2], Amy J. Barger[3], Lennox Lauchlan Cowie[1]
Institution(s): *1. University of Hawaii, 2. University of Texas at Austin, 3. University of Wisconsin Madison*

316.05 – Sharpening Our View of Star Formation in Distant 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. Rather than taking a blurry view of the summed properties of galaxies, our methodology allows
us to paint a detailed picture of how star-formation behaves in galaxies over a wide range of redshifts (0.3<z<2.0).
Here, we present our study of resolved star formation derived using HST/WFC3 IR slitless observations.
The unique capabilities of the WFC3 IR Grism allows us to accurately identify the exact spatial
origin of emission lines in galaxies and determine how star-formation occurs within a galaxy.
Using multiple position angles on the sky, we show that we can accurately derive both the location and the observed wavelengths of these emission lines, which is crucial to derive accurate redshifts for these sources.
We present the properties of [OII], [OIII] and Ha lines and how they relate to their host galaxies properties.
Building upon this, we demonstrate careful forward modeling to derive accurate spatial emission line maps,
and emission line ratios. This allows us to answer fundamental questions; Do galaxies
form stars all at once? Does outside in or inside out star-formation occur? Are there multiple epochs
of star-formation? Is this a function of redshift?
Finally, we demonstrate how these methods can be applied
to JWST data to probe the very earliest epochs of galaxy formation using slitless NIRCam observations.

Author(s): Norbert Pirzkal[2], Barry Rothberg[1], Russell E. Ryan[2]
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316.06 – A Systematic Study of SED Fitting Techniques for Exploring Galaxy Growth at z ~ 2 - 4 Over a Colossal Comoving Volume

We are currently conducting an unprecedented study of how nearly 0.6 million massive galaxies ($M_{star} > 10^{10} M_{\odot}$) grow their stars and dark matter halos over an enormous comoving volume (0.45 Gpc^3) of the $1.9 < z < 3.5$ universe, when cosmic star formation and black hole activity peak, and proto-clusters begin to collapse. This 24 deg^2 study of the SDSS Stripe 82 field utilizes the powerful combination of five photometric surveys (DECam *ugriz*, NEWFIRM K-band, *Spitzer*-IRAC, *Herschel*-SPIRE, and Stripe 82X X-ray), along with future blind optical spectroscopy from the HETDEX project. Central to this study, and other large-area surveys like it, is the dependence on photometric redshifts and spectral energy distribution (SED) fitting to constrain the lookback time and properties of observed galaxies. Unfortunately, these methods are primarily based on galaxies in the local universe and often introduce large uncertainties when applied to high redshift systems. In this poster, we perform systematic tests of the photometric redshift code EAZY (Brammer et al. 2008), and SED fitting codes FAST (Kriek et al. 2009) and MAGPHYS (Da Cunha et al. 2008). We fine-tune input model choices to SED fitting codes (such as SSP, magnitude prior, SFH, IMF, and dust law) using $2 < z < 4$ galaxies from theoretical cosmological simulations, with the goal of better constraining the uncertainty based on model choices. The results of this test are then used to inform the choice of input models used when constraining the properties of galaxies observed in our multi-wavelength study. In the era of large-area photometric surveys with little to no spectroscopic coverage, this work has broad implications for the characterization of galaxies at early cosmic times. We gratefully acknowledge support from NSF grants AST-1614798 and AST-1413652.

Author(s): Sydney Sherman[3], Shardha Jogee[3], Jonathan Florez[3], Matthew L. Stevans[3], Lalitwadee Kawinwanichakij[2], Steven L. Finkelstein[3], Casey J. Papovich[2], Robin Ciardullo[1], Caryl Gronwall[1]
Institution(s): *1. Penn State University, 2. Texas A&M University, 3. University of Texas at Austin*

316.07 – Big Data in the SHELA Field: Investigating Galaxy Quenching at High Redshifts

We present a measurement of the z ~ 4 Lyman break galaxy (LBG) rest-frame UV luminosity function to investigate the onset of quenching in the early universe. The bright-end of the galaxy luminosity function typically shows an exponential decline far steeper than that of the underlying halo mass function. This is typically attributed to negative feedback from past active galactic nuclei (AGN) activity as well as dust attenuation. Constraining the abundance of bright galaxies at early times (z > 3) can provide a key insight into the mechanisms regulating star formation in galaxies. However, existing studies suffer from low number statistics and/or the inability to robustly remove stellar and AGN contaminants. In this study we take advantage of the unprecedentedly large (24 deg^2) *Spitzer*/HETDEX Exploratory Large Area (SHELA) field and its deep multi-wavelength photometry, which includes DECam *ugriz*,

NEWFIRM K-band, *Spitzer*/IRAC, *Herschel*/SPIRE, and X-ray from *XMM-Newton* and *Chandra*. With SHELA's deep imaging over a large area we are uniquely positioned to study statistically significant samples of massive galaxies at high redshifts (z > 3) when the first massive galaxies began quenching. We select our sample using photometric redshifts from the EAZY software package (Brammer et al. 2008) based on the optical and far-infrared imaging. We directly identify and remove stellar contaminants and AGN with IRAC colors and X-ray detections, respectively. By pinning down the exact shape of the bright-end of the z ~ 4 LBG luminosity function, we provide the deepest probe yet into the baryonic physics dominating star formation and quenching in the early universe.

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Institution(s): *1. CUNY NYC College of Technology, 2. Penn State University , 3. Rutgers University, 4. Texas A&M University, 5. University of Texas at Austin*
Contributing team(s): HETDEX Team

316.08 – Constraining the End of Reionization with Deep Lyman-alpha Spectroscopy

An immediately accessible method for studying the intergalactic medium in the reionization era is to measure the equivalent width distribution of Lyman-alpha emission from continuum-selected galaxies with follow-up spectroscopy. To search for Lyman-alpha emission from galaxies at z = 5.5-8.2, we are performing ultra-deep spectroscopic observations of candidate galaxies from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey. We utilize data from the DEIMOS (optical) and MOSFIRE (near-infrared) spectrographs on the Keck 10-meter telescopes, ensuring the comprehensive wavelength coverage of Lyman-alpha emission at z ~ 6-8. We have a total of 1169 hours of spectroscopic integration of galaxies at z > 6: 738 hours for 123 galaxies with DEIMOS and 432 hours for 69 galaxies with MOSFIRE with the additional optical spectroscopic data of our sample galaxies in the GOODS-S field from VLT VANDELS survey. The Lyman-alpha fraction, the ratio of galaxies with detected Lyman-alpha emission to the number of all candidate galaxies observed, is directly measured with the completeness test of our data set by constructing detailed simulations of mock emission lines, which consider observational conditions (e.g., observational depth, wavelength coverage, and sky emission) and the probability distribution function of galaxy photometric redshifts. We present the early result on the Lyman-alpha emission equivalent width distribution of galaxies at z ~ 6 from our analysis of the DEIMOS spectroscopic dataset, determining robust upper limits on the Lyman-alpha emission.

Author(s): Intae Jung[1], Steven L. Finkelstein[1], Rachael C. Livermore[1], Isak Wold[1], Rebecca L Larson[1]
Institution(s): *1. University of Texas at Austin*

316.09 – A Blind Search for Lyα Emission from Galaxies at z = 6-8 with Deep HST Grism Spectra

This project aims to detect Lyα emission lines from z = 6-8 galaxies spectroscopically confirm the redshifts of a large sample of galaxies and to probe the ionization state of the intergalactic medium (IGM) during the epoch of reionization. We use extremely deep data from the Faint Infrared Grism Survey (FIGS; PI: Malhotra) which is currently the most sensitive G102 grism survey, targeting the high-redshift galaxies that were discovered in the CANDELS GOODS fields (Finkelstein et al. 2015). This data set has already proven to be successful as one of these candidates, at redshift z=7.51, has been observed to have Lyα emission detectable with the HST Grism (Tilvi et al 2016). The FIGS data uses five separate roll-angles of HST in an effort to reduce the overall contamination effects of nearby galaxies. We have created a method that accounts for and removes the contamination from surrounding galaxies, and also removes any residual continuum emission from each individual spectrum. We then utilize a MCMC routine to blindly search for significant emission lines using three different methods. First, we compare the results for each galaxy across all roll angles and identify significant lines as those which are detected at the same wavelength in more than one roll angle. Second, we perform a weighted stack of all five roll angles and then search this spectrum for emission lines. Third, we perform a fit to all five roll angles simultaneously. We have found several z > 7 candidates using individual methods which, if confirmed, will increase the number of confirmed galaxies at this epoch by ~50%. We have also detected an emission line at 1.03μm in one galaxy using all three of these methods and are comparing these results with broadband photometry measures. We have proposed for ground-based follow-up observations of this, and several other potential Lyα-emitting galaxies in our sample.

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316.10 – A Magnified View of the Epoch of Reionization with the Hubble Frontier Fields

The Hubble Frontier Fields program has obtained deep optical and near-infrared Hubble Space

Telescope imaging of six galaxy clusters and associated parallel fields. The depth of the imaging (m_AB ~ 29) means we can identify faint galaxies at z > 6, and those in the cluster fields also benefit from magnification due to strong gravitational lensing. Using wavelet decomposition to subtract the foreground cluster galaxies, we can reach intrinsic absolute magnitudes of M_UV ~ -12.5 at z ~ 6. Here, we present the UV luminosity functions at 6 < z < 10 from the complete Hubble Frontier Fields data, revealing a steep faint-end slope that extends to the limits of the data. The lack of any apparent turnover in the luminosity functions means that faint galaxies in the early Universe may have provided sufficient ionizing radiation to sustain reionization.

Author(s): Rachael C. Livermore[2], Steven L. Finkelstein[2], Jennifer M. Lotz[1]
Institution(s): *1. Space Telescope Science Institute, 2. University of Texas at Austin*

316.11 – How Accurately Can We Measure Galaxy Environment at High Redshift Using Only Photometric Redshifts?

We use a powerful synergy of six deep photometric surveys (Herschel SPIRE, Spitzer IRAC, NEWFIRM K-band, DECam ugriz, and XMM X-ray) and a future optical spectroscopic survey (HETDEX) in the Stripe 82 field to study galaxy evolution during the 1.9 < z < 3.5 epoch when cosmic star formation and black hole activity peaked, and protoclusters began to collapse. With an area of 24 sq. degrees, a sample size of ~ 0.8 million galaxies complete in stellar mass above M* ~ 10^10 solar masses, and a comoving volume of ~ 0.45 Gpc^3, our study will allow us to make significant advancements in understanding the connection between galaxies and their respective dark matter components. In this poster, we characterize how robustly we can measure environment using only our photometric redshifts. We compare both local and large-scale measures of environment (e.g., projected two-point correlation function, projected nearest neighbor densities, and galaxy counts within some projected aperture) at different photometric redshifts to cosmological simulations in order to quantify the uncertainty in our estimates of environment. We also explore how robustly one can recover the variation of galaxy properties with environment, when using only photometric redshifts. In the era of large photometric surveys, this work has broad implications for studies addressing the impact of environment on galaxy evolution at early cosmic epochs. We acknowledge support from NSF grants AST-1614798, AST-1413652 and NSF GRFP grant DGE-1610403.

Author(s): Jonathan Florez[3], Shardha Jogee[3], Sydney Sherman[3], Casey J. Papovich[2], Steven L. Finkelstein[3], Matthew L. Stevans[3], Lalitwadee Kawinwanichakij[2], Robin Ciardullo[1], Caryl Gronwall[1]
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Contributing team(s): SHELA/HETDEX

316.12 – Investigating planar distributions of satellites around Local Group analogues

Recent works have claimed that observed planar distributions of galaxies in the Local Group and beyond challenge the structure formation predictions of CDM theory. We perform an analysis of distributions of satellites around 12 Local Group analogue halo pairs and 24 mass-matched isolated haloes from the high-resolution, dissipation-less ELVIS simulations (Garrison-Kimmel et al. 2014). In each analysis, we search for the thinnest plane that can be fit using half of the 30 most massive subhaloes within the virial radius of the host at z=0, and study the kinematics of the result to determine if its components are co-rotating. We then expand this analysis to consider the full kinematic evolution of these planes and others at higher redshifts in the ELVIS merger trees. We find that planes similar to those in the literature are common in the ELVIS simulations, but they are neither uniquely defined or persistent over cosmic time.

Author(s): Rebecca Tippens[1], Michael Boylan-Kolchin[1]
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316.13 – The HST Frontier Fields: Complete Observations and High-Level Science Data Products for All 6 Clusters

The Hubble Space Telescope Frontier Fields program is a large Director's Discretionary program of 840 orbits, to obtain ultra-deep observations of six strong lensing clusters of galaxies, together with parallel deep blank fields, making use of the strong lensing amplification by these clusters of distant background galaxies to detect the faintest galaxies currently observable in the high-redshift universe. The entire program has now completed successfully for all 6 clusters, namely Abell 2744, Abell S1063, Abell 370, MACS J0416.1-2403, MACS J0717.5+3745 and MACS J1149.5+2223,. Each of these was observed over two epochs, to a total depth of 140 orbits on the main cluster and an associated parallel field, obtaining images in ACS (F435W, F606W, F814W) and WFC3/IR (F105W, F125W, F140W, F160W) on both the main cluster and the parallel field in all cases. Full sets of high-level science products have been generated for all these clusters by the team at STScI, including cumulative-depth data releases during each epoch, as well as full-depth releases after the completion of each epoch. These products include all the full-depth distortion-corrected drizzled mosaics and associated products for each cluster, which are science-ready to facilitate the construction of lensing models as well as enabling a wide range of other science projects. Many improvements beyond default calibration for ACS and WFC3/IR are implemented in these data products, including corrections for persistence, time-variable sky, and low-level dark current residuals, as well as improvements in astrometric alignment to achieve milliarcsecond-level accuracy. The full set of resulting high-level science products and mosaics are publicly delivered to the community via the Mikulski Archive for Space Telescopes (MAST) to enable the widest scientific use of these data, as well as ensuring a public legacy dataset of the highest possible quality that is of lasting value to the entire community.

Author(s): Anton M. Koekemoer[1], Jennifer Mack[1], Jennifer M. Lotz[1], David Borncamp[1], Harish G. Khandrika[1], Ray A. Lucas[1], Catherine Martlin[1],Catherine Martlin[1], Blair Porterfield[1], Ben Sunnquist[1], Jay Anderson[1], Roberto J. Avila[1], Elizabeth A. Barker[1], Norman A. Grogin[1], Heather C. Gunning[1],Bryan Hilbert[1], Sara Ogaz[1], Massimo Robberto[1], Kenneth Sembach[1], Kathryn Flanagan[1], Matt Mountain[1]
Institution(s): *1. STScI*
Contributing team(s): HST Frontier Fields Team

316.14 – Search for Efficient Foreground Subtraction Method in 21cm Cosmology

Observations of the HI 21 cm transition line promises to be an important probe into the cosmic Dark Ages and Epoch of Reionization. Detection of this redshifted 21 cm signal is one of the key science goal for several upcoming and future low frequency radio telescopes like Hydrogen Epoch of Reionization Array (HERA), Square Kilometer Array (SKA) and Dark Ages Radio Explorer (DARE). One of the challenges for the detection of this signal is the accuracy of the foreground source removal. Several novel techniques have been explored already to remove bright foregrounds from both interferometric as well as total power experiments. Here, we present preliminary results from our investigation on application of Artificial Neural Networks to detect faint 21cm global signal amidst the sea of bright galactic foreground.

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317 – Black Holes and Cataclysmic Variables Poster Session

317.01 – Modeling SOFIA/FORCAST spectra of the classical nova V5568 Sgr with 3D pyCloudy

We present our first results modelling Nova V5668 Sgr using the pseudo-3D photoionization code pyCloudy (Morisset 2013). V5668 Sgr is a classical nova of the FeII class (Williams et al. 2015; Seach 2015) showing signs of a bipolar flow (Banerjee et al. 2015). We construct a grid of models, which use hour-glass morphologies and a range of C, N, O and Ne abundances, to fit a suite of spectroscopic data in the near and mid-IR obtained between 82 to 556 days after outburst. The spectra were obtained using the FORCAST mid-IR instrument onboard the NASA Stratospheric Observatory for Infrared Astronomy (SOFIA) and the 1.2m near-IR telescope of the Mount Abu Infrared Observatory. Additional photometric data from FORCAST, The STONY BROOK/SMARTS Atlas of (mostly) Southern Novae (Walter et al., 2012) and the American Association of Variable Star Observers (AAVSO) were used to supplement the spectral data to obtain the SED of the nova at different times during its evolution. The work presented here is the initial step towards developing a large database of 1D and 3D models that may be used to derive the elemental abundances and dust properties of classical novae.

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Institution(s): *1. SOFIA/USRA*

317.02 – Hydrodynamic Simulations of Classical Novae: Accretion onto CO White Dwarfs as SN Ia Progenitors

We have continued our studies of accretion onto white dwarfs by following the evolution of thermonuclear runaways on Carbon Oxygen (CO) white dwarfs. We have varied the mass of the white dwarf and the composition of the accreted material but chosen to keep the mass accretion rate at 2 x 10^{-10} solar masses per year to obtain the largest amount of accreted material possible with rates near to those observed. We assume either 25% core material or 50% core material has been mixed into the accreting material prior to the explosion. We use our 1D, lagrangian, hydrodynamic code: NOVA. We will report on the results of these simulations and compare the ejecta abundances to those measured in pre-solar grains that are thought to arise from classical nova explosions. These results will also be compared to recent results with SHIVA (Jose and Hernanz). We find that in all cases and for all white dwarf masses that less mass is ejected than accreted and, therefore, the white dwarf is growing in mass as a result of the accretion and resulting explosion.
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. The results reported herein benefitted from collaborations and/or information exchange within NASA's Nexus for Exoplanet System Science (NExSS) research coordination network sponsored by NASA's Science Mission Directorate.

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317.04 – X-ray Selected Symbiotic Candidates in the Galactic Bulge Survey

The Galactic Bulge Survey (GBS) is a broad, shallow survey of Bulge X-ray sources with extensive multiwavelength support. The limiting sensitivity, about 2×10^{32} erg/s at the Bulge distance, is well suited to finding symbiotic X-ray binaries (SyXBs) containing neutron stars accreting from a cool giant wind, as well as X-ray bright white dwarf systems. Giant counterparts can be securely detected in IR photometry, allowing us to estimate the total number of symbiotics detected by the GBS, and identify a good number of promising candidates. Such an X-ray selected symbiotic sample may be quite different to the traditional symbiotic star population which is usually selected by optical spectroscopy, and consequently biased towards systems with rich line emission. Of the 1640 unique X-ray sources identified by the GBS we find 91 significant matches with candidate Bulge giants. We expect 68 coincidences, so estimate a total sample of about 23 X-ray emitting cool giants detected by the GBS. Most of these are likely to be SyXBs or symbiotics of some type. Narrowing our search to sources coincident to 1", we find 23 matches, with only 8 coincidences expected, so this subsample has a relatively high purity, and likely includes most of the GBS symbiotics. The properties of this subsample are mostly consistent with cool giants, with typical SEDs, long-term lightcurves, and spectra. The sources are inconsistent in color with nearby M dwarfs and show small proper motions, so the foreground contamination is likely small. We present a selection of the best studied objects, focusing on one extremely variable X-ray source coincident with a carbon giant. This is quite an unusual object as carbon stars are rare in the Bulge. The scientific results reported in this article are based on observations made by the Chandra X-ray Observatory and data obtained from the Chandra Data Archive. Support for this work was provided by the National Aeronautics and Space Administration through Chandra Award Numbers GO4-15047X and AR5-16004X issued by the Chandra X-ray Observatory Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of the National Aeronautics Space Administration under contract NAS8-03060.

Author(s): Robert I. Hynes[1], Joshua` D. Wetuski[1], Peter Jonker[5], Manuel Torres[5], Craig O. Heinke[7], Tom Maccarone[6], Danny Steeghs[8], Christopher Britt[2],Christopher Johnson[4], Gijs Nelemans[3]
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317.05 – Newly Uncovered Large-Scale Component of the Northern Jet in R Aqr

R Aqr is a symbiotic system comprised a compact white dwarf and Mira giant star. The interaction of these stars is responsible for the presence of a two-sided jet structure that is seen across the electromagnetic spectrum. X-ray emission from the jet was first discovered in 2000 with an observation by the Chandra X-ray Observatory. Since then follow-up observations have traced the evolution of the X-ray emission from the jet and a central compact source. In X-rays, the NE jet is brighter than the SW jet, but the full extent of the SW jet was larger – before it began fading below the detection threshold. However, we have uncovered evidence for large-scale emission associated with the NE jet that matches the extent of the SW jet. The emission has escaped previous identification because it is near the detection threshold, but it has been present since the first 2000 observation and clearly evolves in subsequent observations. We present our study of the emission from this component of the NE jet, its relationship to multiwavelength observations, and how it impacts our interpretation of the jet-phenomenon in R Aqr.

Author(s): Rodolfo Montez[2], Margarita Karovska[1], Joy S. Nichols[1], Vinay Kashyap[1]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. Smithsonian Astrophysical Observatory*

317.06 – Evolving Nonthermal Electrons in Simulations of Black Hole Accretion

Current simulations of hot accretion flows around black holes assume either a single-temperature gas or, at best, a two-temperature gas with thermal ions and electrons. However, processes like magnetic reconnection and shocks can accelerate electrons into a nonthermal distribution, which will not quickly thermalise at the very low densities found in many systems. Such nonthermal electrons have been invoked to explain the infrared and X-ray spectra and strong variability of Sagittarius A* (Sgr A*), the black hole at the Galactic Center. We present a method for self-consistent evolution of a nonthermal electron population in the GRMHD code KORAL. The electron distribution is tracked across Lorentz factor space and is evolved in space and time, in parallel with thermal electrons, thermal ions, and radiation. At present, for simplicity, energy injection into the nonthermal distribution is taken as a fixed fraction of the local electron viscous heating rate. Numerical results are presented for a model with a low mass accretion rate similar to Sgr A*. We find that the presence of a nonthermal population of electrons has negligible effect on the overall dynamics of the system. Relative to a purely thermal simulation, the radiative power in the nonthermal simulation is enhanced at large radii and at high frequencies. The energy distribution of the nonthermal electrons shows a synchrotron cooling break, with the break Lorentz factor varying with location and time, reflecting the complex interplay between the local viscous heating rate, magnetic field strength, and fluid velocity.

Author(s): Andrew Chael[1], Ramesh Narayan[1], Aleksander Sadowski[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. MIT Kavli Institute for Astrophysics and Space Research*

317.07 – Inferences about supernova physics from gravitational-wave measurements of GW151226

The inferred parameters of the binary black hole GW151226 are consistent with nonzero spin for the most massive black hole, misaligned from the binary's orbital angular momentum. If the black holes formed through isolated binary evolution from an initially aligned binary star, this misalignment would then arise from a kick imparted to the first-born black hole at its birth during stellar collapse. We use simple kinematic arguments to constrain the characteristic magnitude of this kick.

Author(s): Richard O'Shaughnessy[2], Davide Gerosa[1], Daniel Wysocki[2]
Institution(s): *1. California Institute of Technology, 2. Rochester Institute of Technology*

317.08 – Raman-Scattering Line Profiles of the Symbiotic Star AG Peg

The high dispersion H_α and H_β line profiles of the Symbiotic star AG Peg consist of top double Gaussian and bottom components. We investigated the formation of the broad wings with Raman scattering mechanism. Adopting the same physical parameters from the photo-ionization study of Kim and Hyung (2008) for the white dwarf and the ionized gas shell, Monte Carlo simulations were carried out for a rotating accretion disk geometry of non-symmetrical latitude angles from $-7^\circ < \theta < +7^\circ$ to $-16^\circ < \theta < +16^\circ$. The smaller latitude angle of the disk corresponds to the approaching side of the disk responsible for weak blue Gaussian profile, while the wider latitude angle corresponds to the other side of the disk responsible for the strong red Gaussian profile. We confirmed that the shell has the high gas density $\sim 10^{9.85}$ cm^{-3} in the ionized zone of AG Peg derived in the previous photo-ionization model study. The simulation with various HI shell column densities (characterized by a thickness $\Delta D \times$ gas number density n_H) shows that the HI gas shell with a column density $H_{hi} \approx 3 - 5 \times 10^{19}$ cm^{-2} fits the observed line profiles well. The estimated rotation speed of the accretion disk shell is in the range of 44 – 55 kms^{-1}. We conclude that the kinematically incoherent structure involving the outflowing gas from the giant star caused an asymmetry of the disk and double Gaussian profiles found in AG Peg.

Author(s): Seong-Jae Lee[1], Siek Hyung[1]
Institution(s): *1. Chungbuk National University*

317.09 – Searching for Compact Binary Mergers with Advanced LIGO

Several binary black hole mergers were discovered during Advanced LIGOs first observing run, and LIGO is currently well into its second observing run. We will discuss the state of the art in searching for merger signals in LIGO data, and how this will aid in the detection of binary neutron star, neutron-star black hole, and binary black hole mergers.

Author(s): Alexander` Harvey Nitz[1]
Institution(s): *1. AEI Hannover*

318 – Supernovae, Supernova Remnants and Planetary Nebulae Poster Session

318.01 – SuperNovae Analysis aPplication (SNAP): A New Analysis Tool for Understanding the Physics of Supernovae

The explosive death of massive stars, known as supernovae (SNe), are responsible for chemically enriching the universe in heavy elements. Presently, we discover ~300 SNe per year. By 2020 new all sky surveys will be on-line and this will increase to at least 100,000 discovered annually. Additionally, the mechanics and physics of the explosion itself are not solved problems. We need a rapid way to determine the properties of new SNe and a way to compare new models to observations. SNAP is a comparative data base system that contains archived observations, light curve models, and correlation software. We will be able to study SNe events to determine degeneracies in parameters and determine the important physics needed to describe these catastrophic events.

Author(s): Amanda J. Bayless[1]
Institution(s): *1. Southwest Research Institute*

318.02 – Ultraviolet Spectroscopy of a Super-Chandra Type Ia Supernova Candidate

Some type Ia supernovae are overluminous, possibly requiring a progenitor more massive than the Chandrasekhar limit. These have also been found to be even more overluminous in the ultraviolet with observations from the Swift satellite's UltraViolet Optical Telescope. I have observed one of the Super-Chandra candidates with the Hubble Space Telescope to obtain ultraviolet spectroscopy to understand the origin of the luminosity excess. I will present these observations of SN2016ccj and the conclusions from them.

Author(s): Peter J. Brown[1]
Institution(s): *1. Texas A&M / Mitchell Institute*
Contributing team(s): Swift Supernova Team

318.03 – The Global Supernova Project

The Global Supernova Project is worldwide collaboration to study 600 supernovae of all types between May 2017 and July 2020. It is a Key Project at Las Cumbres Observatory, whose global robotic telescope network will provide lightcurves and spectra. Follow-up observations will be obtained on many other facilities, including Swift, VLA, K2, the NTT, IRTF, Keck, and Gemini. Observations are managed by the Supernova Exchange, a combination observatin database and telescope control system run by LCO. Here we report on results from the previous Supernova Key Project, and first results from the Global Supernova Project.

Author(s): Dale Andrew Howell[1]
Institution(s): *1. Las Cumbres Observatory*
Contributing team(s): Global Supernova Project

318.05 – Asteroseismology of Red Supergiants

We explore the question of whether the interior state of massive red supergiant supernova progenitors can be probed with asteroseismology. We have computed a suite of ten models with ZAMS masses from 15 to 25 \msun in intervals of 1 \msun, including the effects of rotation, with the stellar evolutionary code {\it MESA}. We estimate characteristic frequencies and luminosites of convective zones and the power that might be delivered to the surface to modulate the luminous output. Models near the base of the red supergiant branch (RSB) may show no internal modes due to damping in the extended envelope, but models at the tip of the RSB might show characteristic times scales of order hours to a day with amplitudes of 1 -- 10 millimag.

Author(s): Sarafina Nance[1]
Institution(s): *1. The University of Texas at Austin*

318.06 – Studing the Post Merger Evolution of White Dwarf Mergers with FLASH

There is still uncertainty as to the progenitor systems of type Ia supernova (SN Ia). Both single and double degenerate systems have been suggested as progenitors. In a double degenerate system a merger between the two white dwarfs, with total mass at or exceeding the Chandrasekhar mass, leads to the supernova. If the explosion occurs during the merging process it is a violent merger. If an explosion doesn't occur while the stars merge the system becomes a white dwarf of unstable mass. For mergers of this type with differing starting masses it has been shown that during the viscous evolution carbon burning starts far from the center and stably converts the star to oxygen and neon. In this case the star will eventually collapse to a neutron star and not produce an SN Ia. The case of similar mass mergers has been much less explored. Using the results of a smooth particle hydrodynamic merger we simulate the viscous evolution of an equal mass model with FLASH. These simulations test if a similar mass merger can lead to an SN Ia.

Author(s): Malia Jenks[1]
Institution(s): *1. University of Oklahoma*

318.07 – Modelling Sub-Chandrasekhar Mass WD Explosions

Carbon-Oxygen white dwarfs accreting a Helium shell have the potential to explode in the sub-Chandrasekhar mass regime. Previous studies have shown how the ignition of a He shell can either direct ignite the C/O core of the white dwarf at the core-shell interface or propagate a shock wave into the center of the core causing a central ignition. We simulate these progenitors in 1-dimension and examine the composition of the supernovae ejecta. Moving forward to 2- and 3-dimensional simulations we examine the resulting outflows in the context of current supernova observations to begin to answer the question of whether these sub-Chandrasekhar mass explosions occur in nature.

Author(s): Abigail Polin[2], Peter E. Nugent[1]
Institution(s): *1. Lawrence Berkeley Lab, 2. University of California, Berkeley*

318.08 – Modeling Kilonova Spectra Using PHOENIX

Powered by the radioactive decay of *r*-process nuclei, kilonova (alternatively referred to as macronova) emission provides an electromagnetic counterpart to the gravitational waves expected to be produced during binary neutron star and neutron star – black hole mergers. As such, kilonovae are potentially powerful tools for localizing gravitational wave sources and better probing the physics behind the events that generate them. We utilize the detailed Non-LTE code PHOENIX to simulate kilonova spectra by modeling *r*-process-rich ejecta, and we present the very preliminary results of these models.

Author(s): Patrick Vallely[1], Edward A. Baron[1]
Institution(s): *1. University Of Oklahoma*

318.09 – New Measurements of s-Process Enrichments in Planetary Nebulae from High-Resolution Near-Infrared Spectra

We present preliminary results from a high-spectral resolution survey of near-infrared emission lines of neutron-capture elements in planetary nebulae using the Immersion Grating Infrared Spectrometer, IGRINS (Park et al. 2014, SPIE. 9147, 1), which spans the H- and K-bands at spectral resolving power $R \approx 45{,}000$. Both the [Kr III] and [Se IV] lines identified by Dinerstein (2001, ApJL, 550, L223) are seen in nearly all of an initial sample of ≈ 15 nebulae, with improved accuracy over earlier studies based on lower-resolution data (Sterling & Dinerstein 2008, ApJS, 174, 158; Sterling, Porter, & Dinerstein 2015, ApJS, 218, 25). Several new detections of the [Rb IV], [Cd IV], and [Ge VI] lines identified by Sterling et al. (2016, ApJL, 819, 9), as well as a [Br V] line, were made. About half the objects in this sample descend from stars with $[Fe/H] = -0.7 \pm 0.2$ dex, while the remainder have $-0.3 \leq [Fe/H] \leq 0$. We compare the measured enhancements of Se, Kr, Rb, and Cd with predictions of their production by slow-neutron captures (the s-process) during the AGB from theoretical evolutionary models for the corresponding metallicities and various initial masses. New nucleosynthesis calculations were carried out for $[Fe/H] = -0.7$ for initial masses between 1.1 and 3 $M_\odot$ using the Monash stellar evolution and post-processing codes described in Karakas & Lugaro (2016, ApJ, 825, 26), which provides the nucleosynthesis predictions for the metal-rich end of our sample. The Monash models predict enrichments larger by factors of two or more than those from FRUITY (Cristallo et al. 2015, ApJS, 219, 40) and

NuGRID (Pignatari et al. 2016, ApJS, 225, 24) models for the same masses and metallicities. We find that the Monash models are in substantially better agreement than the others with the abundances derived from the IGRINS observations.
This work is based on data taken at the McDonald Observatory of the University of Texas at Austin. IGRINS was developed with support from NSF grant AST-1229522 and the Korean GMT Project of the Korea Astronomy and Space Institute (KASI). AIK acknowledges support from Australian Research Council Future Fellowship FT110100475 and NCS acknowledges support from NSF award AST-1412928.
Author(s): Harriet L. Dinerstein[2], Amanda Karakas[1], Nicholas C. Sterling[3], Kyle Kaplan[2]
Institution(s): *1. Monash University, 2. Univ. of Texas, Austin, 3. University of West Georgia*

318.10 – Photoionization Models of Bromine, Rubidium, and Xenon in Planetary Nebulae

We present numerical simulations of the Br, Rb, and Xe ionization balance in five planetary nebulae (PNe). These neutron-capture elements (atomic number $Z >$ 30) can be enriched by *s*-process nucleosynthesis during the asymptotic giant branch (AGB) evolutionary stage of PN progenitor stars. Recent calculations of photoionization cross sections and rate coefficients for radiative recombination, dielectronic recombination, and charge transfer (Kerlin et al. 2017, in preparation; Sterling & Kerlin 2016, 227th AAS, #238.02; Sterling & Stancil 2011, A&A, 535, A117) allow the Br, Rb, and Xe ionization equilibria to be modeled in PNe for the first time. We have added these elements and their atomic data to Cloudy (Ferland et al. 2013, RMxA&A, 49, 137). We model the PNe IC 418, IC 2501, IC 4191, NGC 2440, and NGC 7027, all of which exhibit emission from multiple Xe ions in the optical data of Sharpee et al. (2007, ApJ, 659, 1265). Multiple Br and Rb ions were also detected in NGC 7027. The model central star temperatures and luminosities, and nebular densities, outer radii, and abundances were optimized to best reproduce the observed intensities of Sharpee et al. We find that IC 418 and NGC 7027 are enriched in Br, Rb, and Xe, in accordance with results for Se and Kr (Sterling et al. 2015, ApJS, 218, 25). Given the small sample size and the weakness of the lines involved, it is not clear whether discrepancies between modeled and observed intensities are due to observational, model, or atomic data uncertainties. This sample will be expanded to include other PNe, such as those in our optical survey (Sherrard et al. poster, this session), which will allow us to test the veracity of the new atomic data for Xe and, for a smaller number of PNe, Br and Rb. Following the methods of Sterling et al. (2015), grids of Cloudy models will be computed to derive ionization correction factors for Br, Rb, and Xe for the first time, allowing their abundances to be determined with higher accuracy than previously possible. We acknowledge support from NSF grant AST-1412928.
Author(s): Nicholas C. Sterling[2], Ryan Porter[1], Courteney Spencer[2], Cameroun G Sherrard[2]
Institution(s): *1. Not Affiliated, 2. University of West Georgia*

318.11 – Abundance Analysis of 17 Planetary Nebulae from High-Resolution Optical Spectroscopy

We present an abundance analysis of 17 planetary nebulae (PNe) observed with the 2D-coudé echelle spectrograph on the 2.7-m Harlan J. Smith telescope at McDonald Observatory. The spectra cover the wavelength range 3600--10,400 Å at a resolution R = 36,700, and are the first high-resolution optical spectra for many objects in our sample. The number of emission lines detected in individual nebulae range from ~125 to over 600. We derive temperatures, densities, and abundances from collisionally-excited lines using the PyNeb package (Luridiana et al. 2015, A&A, 573, A42) and the ionization correction factor scheme of Delgado-Inglada et al. (2014, MNRAS, 440, 536). The abundances of light elements agree with previous estimates for most of the PNe. Several objects exhibit emission lines of refractory elements such as K and Fe, and neutron-capture elements that can be enriched by the *s*-process. We find that K and Fe are depleted relative to solar by ~0.3--0.7~dex and 1-2 dex, respectively, and find evidence for s-process enrichments in 10 objects. Several objects in our sample exhibit C, N, and O recombination lines that are useful for abundance determinations. These transitions are used to compute abundance discrepancy factors (ADFs), the ratio of ionic abundances derived from permitted lines to those from collisionally-excited transitions. We explore relations among depletion factors, ADFs, *s*-process enrichment factors, and other nebular stellar and nebular properties. We acknowledge support from NSF awards AST-901432 and AST-0708429.
Author(s): Cameroun G Sherrard[3], Nicholas C. Sterling[3], Harriet L. Dinerstein[2], Simone Madonna[1], Amanda Mashburn[3]
Institution(s): *1. Instituto de Astrofisica de Canarias, 2. University of Texas, 3. University of West Georgia*

318.12 – Dual Epoch HST Imaging of Kepler's Supernova Remnant -Bright Knot Variability and Search for a Possible SN Progenitor Companion

We have obtained high-angular resolution images of Kepler's Supernova Remnant (SNR), a Type Ia remnant, using the Hubble Space Telescope (HST) at two epochs separated by 10 years. Based on the proper motions of the faint Balmer filaments that are due to fast shocks, we established a distance of 5.1 kpc to the remnant (Sankrit et al. 2016). Here we present the evolution of the bright knots that are due to slower, radiative shocks. HST narrowband images isolating the [N II] 6584A emission were used to identify individual knots on scales of <0.5 arcseconds, and trace changes in their brightnessesbetween the two epochs of observations. We also catalog features that have newly appeared during this ten-year period.

We have also used four WFC3 continuum band images (F336W, F438W, F547M, and F814W) obtained during the second epoch and the ACS F550M band from the first epoch to create a catalog of about 3000 stars in the direction of Kepler's SNR. The stellar properties included in the catalog are the standard U, B, V, I colors and their proper motions. With these data, we have searched for the surviving companion star of the progenitor of Kepler's SNR, but were not able to identify any compelling candidates. None of the stars that are sufficiently close to the possible explosion center, and that have brightnesses expected from a main sequence or red giant companion have sufficiently high proper motions that we can definitively ascribe to kick velocities due to the disruption of the binary system at the time of the supernova explosion.

Author(s): Ilija Medan[6], Ravi Sankrit[4], William P. Blair[1], Kazimierz J. Borkowski[2], Knox S. Long[5], John C. Raymond[3], Brian J. Williams[5]
Institution(s): *1. John Hopkins University, 2. North Carolina State University, 3. Smithsonian Astrophysical Observatory, 4. SOFIA Science Center, 5. Space Telescope Science Institute, 6. USRA*

318.13 – A Survey of Upper Limits on the X-ray Luminosity of a Compact Object in Supernova Remnants

A core-collapse supernova explosion of a massive star (M > 8 Msun) leaves behind a compact stellar object (a neutron star or a black hole). However, there are a large number of supernova remnants (SNRs) in the Galaxy and Magellanic Clouds, in which a compact object has not been detected. Based on the archival Chandra data, we select a large sample of such SNRs, excluding Type Ia SNRs, and place upper limits on the X-ray luminosity for the embedded compact object.

Author(s): Anthony Glenn Rich[1], Ashley Herbst[1], Akshat Tripathi[1], Paul Thongkham[1], Robert Mathews[1], Eric Cooper[1], Nina Clark[1], Alexandria Carino[1],Jayant Bhalerao[1], Sangwook Park[1]
Institution(s): *1. University of Texas at Arlington*

400 – Plenary Talk: Space Weather: Linking Stellar Explosions to the Human Endeavor, Delores Knipp (University of Colorado)

400.01 – Space Weather: Linking Stellar Explosions to the Human Endeavor

Arguably humans have flourished as a result of stellar explosions; we are, after all, stardust. Nonetheless, rapid technology advances of the last 200 years sometimes put society and individuals on a collision course with the natural variability of stellar and solar atmospheres. Human space exploration, routine satellite navigation system applications, aviation safety, and electric power grids are examples of such vulnerable endeavors. In this presentation I will outline how global society relies on 'normal' solar and stellar emissions, yet becomes susceptible to extremes of these emissions. The imprints of these astronomical-terrestrial interactions abound. In particular, I will highlight ways in which stellar/solar bursts link with our space-atmosphere-interaction region, producing multi-year patterns in cosmic ray detection, gorgeous aurora, and deep concern for good order and function of global community.

Author(s): Delores Knipp[1]
Institution(s): *1. University of Colorado Boulder*

401 – AGN and Galaxies

401.01 – New clues about the most extreme obscuration of active black holes

I will present results on the link between the most extreme obscuration of X-rays from active black holes and host galaxy properties. In particular, I will introduce a case study of a nearby galaxy with an obscured active galactic nucleus (AGN). We obtained exquisite integral field spectroscopic observations from the VLT/MUSE in order to probe ionized gas and dust structures. These new data reveal interesting signatures over a range of physical scales. Combined with multi-wavelength observations available from the literature, our new interpretation calls into question the traditional AGN unified model. According to the latter, extreme X-ray obscuration takes place at very small scales within the torus independently from the host galaxy's state. Yet, our results do not correspond the usual alternative scenario of galaxy major merger. Instead, a new scenario is needed to explain our results.

Author(s): Stephanie Juneau[1]
Institution(s): *1. NOAO*
Contributing team(s): S7

401.02 – Investigating the dusty torus of Seyfert galaxies using SOFIA/FORCAST photometry

We present 31.5 μm imaging photometry of 11 nearby Seyfert galaxies observed from the Stratospheric Observatory For Infrared Astronomy (SOFIA) using the Faint Object infraRed CAmera for the SOFIA Telescope (FORCAST). We tentatively detect extended 31 μm emission for the first time in our sample. In combination with this new data set, subarcsecond resolution 1-18 μm imaging and 7.5-13 μm spectroscopic observations were used to compute the nuclear spectral energy distribution (SED) of each galaxy. We found that the turnover of the torus emission does not occur at wavelengths ≤31.5 μm, which we interpret as a lower-limit for the wavelength of peak emission. We used Clumpy torus models to fit the nuclear infrared (IR) SED and infer trends in the physical parameters of the AGN torus for the galaxies in the sample. Including the 31.5 μm nuclear flux in the SED 1) reduces the number of clumpy torus models compatible with the data, and 2) modifies the model output for the outer radial extent of the torus for 10 of the 11 objects. Specifically, six (60%) objects show a decrease in radial extent while four (40%) show an increase. We find torus outer radii ranging from <1pc to 8.4 pc. We also present new 37.1 μm imaging data for 4 of the 11 Seyfert galaxies, as well as 3 additional Seyferts.

Author(s): Lindsay Fuller[7], Enrique Lopez-Rodriguez[8], Christopher C. Packham[7], Cristina Ramos-Almeida[2], Almudena Alonso-Herrero[1], Nancy Levenson[6],James Radomski[8], Kohei Ichikawa[4], Ismael Garcia-Bernete[2], Omaira Gonzalez-Martin[3], Tanio Diaz Santos[5], Mariela Martinez-Paredes[3]
Institution(s): *1. Centro de Astrobilogia (CAB,CSIC-INTA), 2. Instituto de Astrofisica de Canarias, 3. Instituto de Radioastronomia y Astrofisica, 4. National Astronomical Observatory of Japan, 5. Nucleo de Astronomia de la Facultad de Ingenieria, 6. Space Telescope Science Institute, 7. University of Texas at San Antonio, 8. University Space Research Association*

401.04 – X-ray Imaging and Spectroscopy of the Andromeda Galaxy's Nuclear Feedback

The central region of the Andromeda galaxy (M31) is currently quiescent in both AGN and star formation, but shows strong indications for recent AGN activity. We have conducted a systematic analysis of Chandra and XMM-Newton X-ray observations of the region. The diffuse X-ray emission from the high spatial resolution Chandra observations reveals interesting substructures (e.g., cavities), as well as the global distribution of diffuse hot gas in the region. The X-ray grating spectra from the XMM-Newton observations show enhanced forbidden lines of He-like Oxygen, Neon, and Nitrogen Kalpha triplets, as well as signatures for multi-temperature hot gas. We find that these results can be well interpreted by an AGN-relic model, which we have developed, suggesting that galaxy is a bright AGN about 0.4 Myrs ago. In addition, we also present evidence for resonance scattering effects, which broaden the spatial distribution of the relevant line emission and provide a sensitive probe of the hot gas turbulent motion. This study demonstrates the power of the X-ray spectroscopy, which will be greatly improved by upcoming X-ray missions, in our understanding of the recurrence history or frequency of AGN and the galaxy feedback in general.

Author(s): Q. Daniel Wang[1], Shuinai Zhang[1], Shawn Roberts[1]
Institution(s): *1. Univ. of Massachusetts*

401.05D – Understanding Local Luminous Infrared Galaxies in the Herschel Era

Luminous and ultraluminous infrared galaxies [(U)LIRGs] are some of the most extreme objects in the universe with their elevated star formation rates and/or presence of a powerful AGN, playing a central role in the evolution of galaxies throughout cosmic history. The 201 local (U)LIRGs (z<0.088) within the Great Observatories All-Sky LIRG Survey (GOALS) provide an unmatched opportunity to characterize the diverse properties in a large, statistically significant sample, in addition to comparisons with their high redshift counterparts. In this thesis talk I will first present the Herschel PACS and SPIRE far infrared image atlas of the entire GOALS sample (encompassing the 70-500 micron wavelength range), and demonstrate the excellent data quality. The Herschel GOALS images presented here are the highest resolution, most sensitive and comprehensive far-infrared imaging survey of the nearest (U)LIRGs to date. This allows us for the first time to directly probe the critical far infrared and submillimeter wavelength regime of these systems, enabling us to accurately determine the bolometric luminosities, infrared surface brightnesses, star formation rates, and dust masses and temperatures on spatial scales of 2-5 kpc. In addition, the superb resolution of Herschel means we can resolve many of the galaxy pairs and systems within the GOALS sample, allowing us to measure far infrared fluxes of component galaxies. Finally, using the Herschel photometry in conjunction with Spitzer, WISE, and IRAS data, I will show our first results on the global properties of (U)LIRGs such as their average 3-500 micron infrared SEDs and far infrared colors, and compare them to lower infrared luminosity objects. We will also compare and contrast their infrared SED shapes with previously published SED templates from the literature. If time permits, I will also show initial results from our rest-frame optical spectroscopy program on z~2.3 infrared selected galaxies in the COSMOS field.

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Institution(s): *1. Canada France Hawaii Telescope, 2. Infrared Processing & Analysis Center, 3. NASA Herschel Science Center, 4. National Radio Astronomy Observatory, 5. Observatoire de l'Universite de Geneve, 6. Pontificia Universidad Catolica de Chile, 7. SETI Institute, 8. Spitzer Science Center, 9. Universidad Diego Portales, 10. Universitat de Barcelona (IEEC-UB), 11. University of Hawaii Hilo, 12. University of Hawaii, Institute for Astronomy, 13. University of Virginia*

Contributing team(s): Great Observatories All-Sky LIRG Survey, Cosmic Evolution Survey

401.06 – The Brightest Galaxies in the Universe: Gravitationally Lensed Submm Galaxies at 1

We present new near-IR images from HST Cycle 24 of some of the most luminous galaxies in the Universe: submillimeter galaxies identified via Planck, Herschel, and WISE fluxes and confirmed with the Large Millimeter Telescope to lie at redshifts 1<z<4 with log(L_IR)~13-14. The new HST images -- more than half are in hand of our sample of 22 galaxies -- confirm previous suggestions that all these extremely bright sources are both intrinsically luminous and are strongly gravitationally lensed and magnified. Most show clear partial or complete Einstein rings due to single chance alignment with massive foreground galaxies, while some are lensed by foreground galaxy clusters. By constructing lens models from the HST images, we can search for sub-kpc spatially resolved clues about what powers these extreme starburst galaxies. Correcting for the measured gravitational lensing magnification then lets us measure their true star formation rates and molecular gas masses: typical intrinsic SFR~1000-3000 Msun/yr and log(M_CO/Msun)~11-12.

Author(s): James D. Lowenthal[3], Min Su Yun[5], Patrick Kamieneski[5], Q. Daniel Wang[5], Itziar Aretxaga[1], David Hughes[1], Kevin Harrington[4], Derek Berman[5], Roberto Terlevich[2]
Institution(s): *1. INAOE, 2. IOA/University of Cambridge, 3. Smith College, 4. U. Bonn, 5. UMass Amherst*

401.07 – The MEDIDO Survey: Dark Matter in Low Dispersion Stellar Systems

We will present preliminary results of the Medido Survey. The Survey focuses on dwarf galaxies of various types, as well as Milky Way globular clusters. We have been gathering data at the McDonald Observatory using the VIRUS-W spectrograph, which is capable of resolving velocity dispersions slightly above 10 km/s. For the galaxies, our focus is to improve kinematics in the central regions in order to tackle the cusp/core discrepancy between observations and models. In the case of the globular clusters, we map kinematics out to about 2 half-light radii with the goal of testing if any dark matter content can be detected or if dark matter can be confidently ruled out for these systems.

Author(s): Eva Noyola[1], Maria Jose Bustamante[1]
Institution(s): *1. UT, Austin*

401.08 – Using OJ287 observations to probe back reaction of gravitational waves

The presence of a supermassive binary black hole (BBH) central engine in OJ287 is revealed by impact flares which arise from the secondary impacting the accretion disk of the primary. These flares have been observed since 1913 from the study of old photographic plates and from recent observational campaigns, 9 events in total. In addition, the secondary induces flares by affecting the accretion rate of the primary. The records for the latter events start in 1900, and they have been observed for each of the 10 cycles since then. Because of orbital precession, the impact flares times do not follow any simple rule. However, since the BBH - accretion disk impact model was proposed in 1995, the optical flux behavior of OJ287 has become highly predictable. The latest predictions were given for the late 2015 - early 2017 season. These have now been verified. The impact flare started on 2015 November 25, during the Centenary of Einstein's General Relativity, followed by induced accretion flares which peaked on 2016 March and 2016 October. The nine impact flares specify the two parameters of the standard accretion disk and the 6 parameters of the BBH orbit uniquely. The main remaining uncertainty has to do with the exact way the gravitational wave (GW) emission affects the orbit. The impact flare observations demand that the GW emission is a combination of the instantaneous and hereditary effects appearing at the Post Newtonian orders 2.5PN, 3.5PN and 4PN, and all of them have to be incorporated while modeling the dynamics of the central engine BBH in OJ287. Previously, only the standard 2.5PN "Newtonian" GW terms have been used. We develop a simplified way of incorporating the higher order General Relativistic effects and obtain revised estimates for various BBH parameters. The improved BBH dynamics makes specific predictions for the occurrences of the expected impact flares in future and thereby provide additional strong field tests of General Relativity.

Author(s): Mauri J. Valtonen[9], Lankeswar Dey[6], Achamveedu Gopakumar[6], Staszek Zola[3], Kozo Sadakane[5], Katsura Matsumoto[5], Dan Reichart[7], Daniel B. Caton[1], Kosmas Gazeas[8], Stefano Ciprini[2], Helen Jermak[4], Iain Steele[4], Andrei Berdyugin[9], Kari Nilsson[9]
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402 – Extrasolar Planets: Characterization and Theory

402.01 – How do surfaces, clouds and refraction modify the effective radius of a transiting exoplanet?

Lecavelier des Etangs et al. (2008) showed that the effective radius of a transiting exoplanet with a constant atmospheric scaleheight occurs at an altitude where the optical depth through the atmospheric limb is about 0.56. Although this formalism is only true for a clear atmosphere, it has nevertheless been applied to cloudy atmospheres by some members of the exoplanet community by locating the effective radius at the top of optically thick clouds if the optical depth of the gas is less than 0.56 at the top of the clouds. We have derived an analytical formalism which includes the effect of surfaces, optically thick clouds and refractive boundaries. We show how these various "surfaces" modify the location of the effective exoplanet radius, their impact on the transmission spectra of transiting exoplanets, and how our results differ from the approach described above for treating clouds.

Author(s): Yan Betremieux[1], Mark R. Swain[1]
Institution(s): *1. JPL*

402.02 – Clouds in exoplanet atmospheres: comparison of two apparently similar giant planets

We present a study aimed at a better understanding of the physics of clouds, which have been shown prevalent in hot Jupiter atmospheres. We compare and contrast the atmospheric spectra of WASP-67 b and HAT-P-38 b, part of our HST/WFC3 and Spitzer observation programs of exoplanets in transmission spectroscopy and secondary eclipses. These two planets lie in a very similar region of the equilibrium temperature-surface gravity parameter space and their compared analysis is therefore particularly significant.
With the help of retrieval exercises on the molecules characterizing the 1.1-1.7 microns WFC3 spectra, we discuss which conclusions can be drawn about the atmospheric processes of these two giant planets.

Author(s): Giovanni Bruno[8], Nikole K. Lewis[8], Kevin Stevenson[8], Drake Deming[9], Joe Filippazzo[8], Jonathan D. Fraine[8], Matthew Hill[8], Brian Kilpatrick[2],Michael R. Line[1], Caroline Morley[5], Hannah Wakeford[6], Karen A Collins[10], Dennis M Conti[3], Joseph Garlitz[4], Joseph Rodriguez[7]
Institution(s): *1. Arizona State University, 2. Brown University, 3. Conti Private Observatory, 4. Garlitz Private Observatory, 5. Harvard University, 6. NASA Goddard Space Flight Center, 7. Smithsonian Center for Astrophysics, 8. Space Telescope Science Institute, 9. University of Maryland, 10. Vanderbilt University*

402.03 – Modelling the phase curve and occultation of WASP-43b with SPIDERMAN

Presenting SPIDERMAN, a fast code for calculating exoplanet phase curves and secondary eclipses with arbitrary two dimensional surface brightness distributions. SPIDERMAN uses an exact geometric algorithm to calculate the area of sub-regions of the planet that are occulted by the star, with no loss in numerical precision. The speed of this calculation makes it possible to run MCMCs to marginalise effectively over the underlying parameters controlling the brightness distribution of exoplanets. The code is fully open source and available over Github. We apply the code to the phase curve of WASP-43b using an analytical surface brightness distribution, and find an excellent fit to the data. We are able to place direct constraints on the physics of heat transport in the atmosphere, such as the ratio between advective and radiative timescales at different altitudes.

Author(s): Tom Louden[1]
Institution(s): *1. University of Warwick*

402.04 – Precise Masses in the WASP-47 Multi-Transiting Hot Jupiter System

We present precise radial velocity observations of WASP-47, a star known to host a hot Jupiter, a distant Jovian companion, and, uniquely, two additional transiting planets in short-period orbits: a super-Earth in a 19 hour orbit, and a Neptune in a 9 day orbit. We combine our observations, collected with the HARPS-N spectrograph, with previously published data to measure the most precise planet masses yet for this system. When combined with new stellar parameters (from analysis of the HARPS-N spectra) and a reanalysis of the transit photometry, our mass measurements yield strong constraints on the small planets' compositions. Finally, we probabilistically constrain the orbital inclination of the outer Jovian planet through a dynamical analysis that requires the system reproduce its observed parameters.

This work was supported by the National Science Foundation Graduate Research Fellowship Program. HARPS-N was funded by the Swiss Space Office, the Harvard Origin of Life Initiative, the Scottish Universities Physics Alliance, the University of Geneva, the Smithsonian Astrophysical Observatory, the Italian National Astrophysical Institute, the University of St. Andrews, Queens University Belfast, and the University of Edinburgh.

Author(s): Andrew Vanderburg[2], Juliette Becker[3], Lars A Buchhave[1], Annelies Mortier[4], David W. Latham[2], David Charbonneau[2], Mercedes Lopez-Morales[2]
Institution(s): *1. Copenhagen University, 2. Harvard-Smithsonian Center for Astrophysics, 3. University of Michigan, 4. University of St. Andrew's*
Contributing team(s): the HARPS-N Collaboration

402.05D – Can we measure protoplanetary disk masses with CO observations?

Gas in protostellar disks provides the raw material for giant planet formation and controls the dynamics of the planetesimal-building dust grains. Accurate gas-mass measurements provide insight into disk evolution and also help us to understand the formation environments of planets. While carbon monoxide (CO) is usually too optically thick to probe the entire mass budget in giant-planet forming regions, rare isotopologues of CO have been used as gas mass tracers for disks, assuming an interstellar CO/H_2 abundance ratio. However, our chemical models of T-Tauri disks show that CO beyond 20 AU around a solar-type star is dissociated by He^+, with the carbon becoming sequestered in complex organic molecules. Over million-year time scale, CO dissociation leads to a CO/H_2 ratio that decreases both with distance from the star and as a function of time.

In this dissertation talk, I will present radiative transfer simulations that assess the accuracy of CO-based disk mass measurements. The combination of CO chemical depletion in the outer disk and optically thick emission from the inner disk leads to gas mass estimates that are too low by over an order of magnitude, given the standard assumptions of interstellar CO/H_2 ratio and optically thin emission. Furthermore, the million-year timescale of CO depletion introduces an age/mass degeneracy into observations. To reach factor of a few accuracy for CO-based disk mass measurements, we suggest that observers and modelers adopt the following strategies: (1) select the low-J transitions; (2) observe multiple CO isotopologues and use either intensity ratios or normalized line profiles to diagnose CO depletion; and (3) use spatially resolved observations to measure the CO abundance distribution.

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Institution(s): *1. The University of Texas at Austin, 2. University of Delaware*

402.06 – A Retrieval Architecture for JWST Observations of Directly Imaged Exoplanets

I present a new modeling and retrieval code for atmospheres of directly imaged exoplanets designed for use on JWST observations, extending my previous work on transiting planets. I perform example retrievals of temperature-pressure profiles, common molecular abundances, and basic cloud properties on existing lower-resolution spectra and on simulated JWST data using forward model emission spectra for planned NIRISS and NIRCam targets. From these results, I estimate the expected return on prospective JWST observations in information-theoretic terms using the mutual information metric.

Author(s): Alex Howe[1]
Institution(s): *1. University of Michigan*

402.07 – Community Targets for JWST's Early Release Science Program: Evaluation of Transiting Exoplanet WASP-63b.

We present observations of the Hubble Space Telescope (HST) ``A Preparatory Program to Identify the Single Best Transiting Exoplanet for JWST Early Release Science" for WASP-63b, one of the community targets proposed for the James Webb Space Telescope (JWST) Early Release Science (ERS) program. A large collaboration of transiting exoplanet scientists identified a set of ``community targets" which meet a certain set of criteria for ecliptic latitude, period, host star brightness, well constrained orbital parameters, and strength of spectroscopic features. WASP-63b was one of the targets identified as a potential candidate for the ERS program. It is presented as an inflated planet with a large signal. It will be accessible to JWST approximately six months after the planned start of Cycle 1/ERS in April 2019 making it an ideal candidate should there be any delays in the JWST timetable. Here, we observe WASP-63b to evaluate its suitability as the best target to test the capabilities of JWST. Ideally, a clear atmosphere will be best suited for bench marking the instruments ability to detect spectroscopic features. We can use the strength of the water absorption feature at 1.4 μm as a way to determine the presence of obscuring clouds/hazes. The results of atmospheric retrieval are presented along with a discussion on the suitability of WASP-63b as the best target to be observed during the ERS Program.

Author(s): Brian Kilpatrick[2], Patricio Cubillos[7], Giovanni Bruno[8], Nikole K. Lewis[8], Kevin B. Stevenson[8], Hannah Wakeford[4], Jasmina Blecic[5], Adam Seth Burrows[6], Drake Deming[12], Kevin Heng[10], Michael R. Line[1], Nikku Madhusudhan[11], Caroline Morley[3], Ingo P. Waldmann[9]
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Contributing team(s): The Transiting Exoplanet Early Release Science Community (Stevenson et al. 2016)

403 – Preparing for JWST Observations: Insights from Solar System GTO Programs

Opportunities to propose Early Release Science (ERS) observations for the James Webb Space Telescope (JWST) are now available. JWST General Observer (GO) program opportunities will be available in just a few months (November 2017). How can you prepare a successful JWST observing program? Here the Guaranteed-Time Observers (GTO) will describe how they turned their science into JWST observing programs, including JWST proposal planning tool use case examples. This session will focus primarily on Solar System JWST GTO Programs.

403.01 – Good Things in Small Packages: Asteroid Observations with JWST

Many aspects of small body science that are of great current interest are addressable by JWST, and just as

HST observations of asteroids set the stage for in situ measurements of these objects, we expect JWST to extend our understanding further still. In particular, NIRSpec and NIRCam observations in the 3-µm region and MIRI observations will provide data unobtainable from the ground save for a handful of the brightest asteroids. In contrast, JWST will allow these measurements to be made for practically every known main belt asteroid and a large fraction of near-Earth asteroids, enabling study of their mineralogies and volatile inventories. We will describe the science cases for several possible JWST asteroid projects, including study of the largest asteroids, a reconnaissance of objects co-orbiting with major planets, and observations of select, intriguing near-Earth objects unrepresented in our meteorite collections, all at wavelengths and with a sensitivity unachievable from Earth. These possible projects will all provide high-priority planetary science and showcase JWST's unique capabilities.

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403.02 – How JWST will bring light to the nature of trans-Neptunian objects through GTO observations.

Trans-Neptunian objects (TNOs) are a compositionally and dynamically diverse population of minor bodies. They reside in the outer regions of the Solar System and preserve a record of the significant dynamical dispersal of the protoplanetesimal disk that followed the era of planet formation. Dynamical studies of the ~1500 known TNOs have provided a surprisingly complex picture of their formative history, and thermal modeling has resulted in the estimation of size and albedo for more than 100 objects. Despite this advance, however, very little is known about the composition of the TNOs themselves: most objects are much too faint for detailed ground-based spectroscopic characterization, especially in the NIR, and in many of the cases, surface components inferred in low S/N data, lack confirmation.

The unique capabilities of the James Webb Space Telescope will provide an exceptional opportunity for collecting data from 0.7 to ~10 µm, using preferably NIRCam, NIRSPec, and MIRI in photometric and spectroscopic modes. In the lifetime of JWST, similar data could be obtained for an unprecedented number of TNOs. The study of such a collection of data would considerably extend the actual sparse knowledge of their physical properties, which is critical for elucidating the early formation conditions and evolutionary processes experienced by the outer Solar System bodies, that provides the key reference point for comparison with other planetary systems.

For this GTO call, we have focused on a diverse set of targets ranging from the brightest, largest, volatile-rich dwarf planets to the smaller and silicate- or organic-rich Centaurs. Observations have been crafted for each target to provide crucial information in order to answer a number of different scientific open questions.

In this talk, I will detail the collection of data that we aim to gather from TNOs and I will present the different strategies adopted depending on the expected flux from the object, on the SNR and resolution required to achieve our goals, and also on the optimization of the total time needed for each exposure once overheads are accounted.

I would like to acknowledge J. Stansberry for giving me the opportunity to approach JWST at this early epoch.

Author(s): Noemí Pinilla-Alonso[1]
Institution(s): *1. Florida Space institute (University of Central Florida)*

403.03 – Exploring the Ice Giants with JWST

The Ice Giants Uranus and Neptune are among the least-explored environments in our Solar System, having been visited only once, by Voyager 2 in 1986 and 1989, respectively. Their bulk properties and composition, intermediate between the hydrogen-rich gas giants and the smaller terrestrial worlds, make them representative of a planetary class that may be commonplace in other planetary systems. Furthermore, their small angular diameter, low atmospheric temperatures, and dynamic and ever-changing atmospheres make them tantalising infrared targets for JWST. This presentation will reveal the scientific rationale and requirements for a long-term program of JWST spectroscopic mapping of these two worlds. Specifically, the MIRI instrument can be used to determine the 3-dimensional temperature structure to understand (i) seasonal atmospheric circulation from the equator to the poles, (ii) the relation between temperatures, visible atmospheric banding and storm phenomena; and (iii) to discover the unknown circulations and wave phenomena shaping their middle atmospheres. JWST spectra will also allow us to search for and map chemical species produced from photochemistry (e.g., hydrocarbons derived from methane photolysis), from vertical mixing (e.g., disequilibrium species), and from external sources (e.g., HCN and oxygen compounds delivered by comets, ring rain and interplanetary dust). Furthermore, near-infrared imaging and spectroscopy with NIRCAM and NIRSpec will provide detailed characterisations of ice-giant cloud and haze formation and their evolution with time, as well as revealing how auroral processes (observed via H_3^+ emission) influence the middle atmosphere. JWST will not only enable intercomparison of these atmospheric processes on two very different worlds (Uranus with its extreme tilt and sluggish mixing; Neptune with its powerful internal heat source), but also mature our understanding of how ice giant phenomena compare to both gas giant and terrestrial atmospheric processes. We propose that preliminary mapping observations from the GTO programme will initiate a long-term programme of ice giant characterisation over the duration of JWST's lifetime.

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Institution(s): *1. AURA, 2. JPL, 3. LMD, 4. Southwest Resarch Institute, 5. University of Leicester, 6. University of Oxford*

403.04 – Unique Spectroscopy and Imaging of Terrestrial Planets with JWST

In this talk, I will present the main capabilities of the James Webb Space Telescope (JWST) for performing observations of terrestrial planets, using Mars as a test case. The distinctive vantage point of JWST at the Sun-Earth Lagrange point (L2) will allow sampling the full observable disk, permitting the study of short-term phenomena, diurnal processes (across the East-West axis) and latitudinal processes between the hemispheres (including seasonal effects) with excellent spatial resolutions (0.07 arcsec at 2 um). Spectroscopic observations will be achievable in the 0.7-5 um spectral region with NIRSpec at a maximum resolving power of 2700, and with 8000 in the 1-1.25 um range. Imaging will be attainable with NIRCam at 4.3 um and with two narrow filters near 2 um, while the nightside will be accessible with several filters in the 0.5 to 2 um. Such a powerful suite of instruments will be a major asset for the exploration and characterization of Mars, and terrestrial planets in general. Some science cases include the mapping of the water D/H ratio, investigations of the Martian mesosphere via the characterization of the non-LTE CO_2 emission at 4.3 um, studies of chemical transport via observations of the O_2 nightglow at 1.27 um, high cadence mapping of the variability dust and water ice clouds, and sensitive searches for trace species and hydrated features on the planetary surface.

Author(s): Geronimo Luis Villanueva[1]
Institution(s): *1. NASA's GSFC*
Contributing team(s): JWST Mars team

404 – AAS Education Prize: Growth of Astronomy Education in Chile: A Late But Successful Story, Hernán Quintana (Pontificia Universidad Catolica)

404.01 – Growth of Astronomy Education in Chile: a late but successful story

The first present international observatories were stablished in Chile by 1963, at a time when local astronomy was devoted to traditional Fundamental Astronomy research, as in most other Latin-american countries. For over 35 years little was achieved in the way of effectively developing a healthy university teaching in the field, in spite of initiatives started and helped in the mid-sixties by some astronomers at CTIO or ESO. Up to 1998, when a second try to start a university degree, this time at U. Católica, was unexpectedly successful, the number of Chileans astronomers had remained constant or slightly decreased. The number started to grow significantly when the new degree attracted the keen interest of students, reaching the potential widely recognized since a long time. Today some 13 universities have astronomy courses or degrees and the number of students and post-docs are in the hundreds.The series of events and university policies originally prevailing in the country, and the changes that allowed the new state of affairs, will be reviewed and described. This will include the barriers and difficulties encountered, and the ways devised to overcome these.

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