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101 — Kavli Foundation Lecture: Key Outstanding Questions in Galaxy Formation and How to Answer Them, Alice Shapley (UCLA)

101.01 — Key Outstanding Questions in Galaxy Formation and How to Answer Them

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Understanding the formation and evolution of galaxies remains one of the great challenges of modern cosmology. Key outstanding questions include: What are the physical processes driving the formation of stars in individual galaxies? How do galaxies exchange matter and energy with their intergalactic environments? How do the impressive variety of galactic structures that we observe today assemble? How do supermassive black holes affect the evolution of their host galaxies? And how do large-scale structures of galaxies assemble across cosmic time? I will address these important questions in galaxy formation using new results from powerful ground-based and space-based facilities. I will also look ahead to future progress with upcoming facilities.

102 — The Solar System Poster Session

102.01 — Changing linear polarization properties in the dust tail of comet C/2012 S1 (ISON)

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Polarization measurements made with the STEREO/SECCHI COR1 and COR2 coronagraphs during the perihelion passage of sungrazing comet C/2012 S1 (ISON) in November 2013 are presented and compared with earlier measurements made of Kreutz sungrazing comet C/2011 W3 (Lovejoy). Comet ISON was an Oort Cloud object, probably entering the solar system for the first time. Strong evidence was found for a radical change in the polarization properties once the tail particles approached within 10 solar radii of Sun center. Above this apparent threshold, the polarization properties of Comet ISON appeared very similar to those seen previously for Comet Lovejoy, with high positive polarization, and a broad negative branch reaching out to an inversion point between 40-50 degrees. Below 10 solar radii the polarization levels drop dramatically; an effect not seen for Comet Lovejoy. We conclude that radiation processes close to the Sun, and possibly starting as far out as 0.25 AU, are responsible for the high levels of polarizations seen in both comets, and that the sublimation of olivines and pyroxenes is responsible for the precipitous drop in Comet ISON's polarization below 10 solar radii.

102.02 — Earth At Mars

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With its current chemical makeup, Earth would freeze solid if placed at Mars' orbit. This research explores the possibility of an Earth like planet maintaining liquid water in an orbit like Mars. We used the Global Circulation Model software (ModelE) provided by the Goddard Institute for Space Studies to reposition Earth into the orbit of Mars. We then increase the amount of greenhouse gasses, primarily CO_2 , in the atmosphere in an attempt to keep parts of the planet from freezing solid.

102.03 — Carbonyl sulfide (OCS): Detection in two Oort cloud comets and upper-limits in two Jupiter-family comets.

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Comets are thought to retain volatiles from the time of their formation; therefore, characterizing their composition should provide insights into the conditions present in the early solar system. Chemical diversity has been noted among comets based on measurements at all wavelengths, including near-IR studies of parent volatiles. Of these molecules, OCS is particularly underrepresented in parent volatile studies, having been targeted in only a small subset of comets (four OCCs so far). Newer instruments, such as the high-resolution, near-infrared iSHELL spectrograph at the NASA-IRTF on Maunakea, HI, with its large spectral grasp and active M-band guiding capabilities, now enable routine sampling of OCS emissions near 4.9 μm along with other molecules, thus we will be able to begin establishing statistics for the OCS content of comets. We targeted OCS in comets 46P/Wirtanen, 21P/Giacobini–Zinner, and C/2015 ER61 in 2017-2018 using iSHELL, as well as in C/2002 T7 (LINEAR) using CSHELL in 2004. We will present production rates and mixing ratios (with respect to H_2O) of OCS for these comets and will place our results in the context of comets measured to date. This work was supported by the NASA Earth and Space Science Fellowship, Solar System Workings, Solar System Observations, and Astrobiology Programs, and NSF Solar and Planetary Research Grants.

103 — Instrumentation: Ground Based or Airborne & Computation Poster Session

103.01 — A 1000x Stabler Spectrograph using an Interferometer with Crossfaded Delays

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We establish one step along a technical route to achieving cm/s scale accuracy for astronomical spectrographs over long time scales, which is critical for the characterization of earth sized exoplanets and measurement of cosmic redshift drift over years. Using a new method called "crossfading" for externally dispersed interferometers (EDI) to get highly robust spectra, we have recently demonstrated a factor of 1000x reduction in the net shift of an EDI measured ThAr line to a deliberate simulated wavelength translation of the detector. This 1000x gain in disperser stability can be combined with conventional stability gains afforded by fiber scramblers, vacuum tanks, and thermal control, to provide an additional 2 to 3 orders of magnitude reduction in the net PSF shift drift. Crossfading combines high and low delay process signals using strategic weightings to cancel the net reaction to a wavelength drift of the detector. This can be applied by deploying interferometers having a stepped mirror that produces two simultaneous delays, or can be applied to a single delay that overlaps the spectral response of the ordinary spectrum, and for that case all time scale drifts are mitigated. Crossfading also mitigates increases in PSF width and asymmetric distortions.

103.02 — Characterization of Teledyne HAWAII-4RG-15 Infrared Detector Arrays

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With funding from NSF, the University of Hawaii Institute for Astronomy, in partnership with Teledyne Imaging Sensors, LLC, have, over the past decade, developed the HAWAII-4RG-15 near infrared detector arrays with a cut-off wavelength of 2.5 micrometers. The "R" in the name indicates the presence of reference pixels, the "G" stands for guide-window mode, and the "15" indicates the pixel size in micrometers. These devices are usually abbreviated as H4RG-15.

The H4RG-15 detector arrays can operate with up to 64 output amplifiers, but in our testing program, they were operated by a single Teledyne SIDECAR ASIC with 32 signal channels. In addition to the frame of 4 rows and columns of reference pixels that

the older H2RG devices are using, the H4RG-15 provides reference pixels that can be read out interleaved with the IR-sensitive science pixels. In our testing, we routinely used the interleaved reference pixels, leading to a full-frame read-out time of 5.4 s.

As part of the development program, Teledyne had produced three near-science-grade detector arrays with two different passivation processes. One of these, referred to as PV1 here, turned out to be clearly superior with respect to persistence effects.

The telescope tests of the best (PV1) device were done using the ULB-Cam test system restricted to the J and H bands. These tests showed that under conditions of low electronic pickup noise, the use of the interleaved reference pixels does not offer an advantage over the use of the frame reference pixels. Most importantly, the telescope tests with standard dithering data acquisition showed no noticeable detector persistence in the broad J and H filters.

The laboratory tests showed only minimal, short duration persistence on the PV1 device, and moderate persistence on the PV2 devices. For both flavors of detector material, localized persistence near bad pixel areas was noted and my be caused by internal stress of the detector material.

The detector arrays show non-linear photometric response near the saturation level due to the changes in photodiode capacitance with remaining bias voltage. This non-linearity can be fitted with a polynomial and corrected for.

103.03 — An Optical System for Multi-wavelength Intensity Interferometry with the Southern Connecticut Stellar Interferometer

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The Southern Connecticut Stellar Interferometer is an astronomical intensity interferometer consisting of two telescopes. Each is currently equipped with a single-photon avalanche diode (SPAD) detector, and an ultra-fast timing module correlates counts between both photon detectors. The interferometer has previously demonstrated intensity correlations using the 1-pixel SPADs and extremely narrow band pass filters but was limited in the amount of light that could be collected, and therefore the signal-to-noise ratio that could be achieved. SCSU's recent acquisition of an 8-pixel SPAD detector has allowed for a new possibility: a different wavelength of light could be directed towards each of the 8 pixels of the detector, thus conducting 8 independent intensity interferometry experiments at the same time, if this could be implemented at both telescopes. Using materials and resources available in the Astronomical Instrumentation Laboratory at Southern Connecticut State University, an optical system has been developed to work toward this goal but outfitting the first telescope in this way. The light from the telescope is collimated and directed toward a reflective diffraction grating. This is then re-imaged using a second lens and directed onto the pixels of the photon detector. These optical components have been placed inside an aluminum housing and can be mounted to the telescope for test observations. A status report will be given on the observations so far. If this can be replicated at the other telescope, the signal-to-noise ratio achievable with the instrument could be improved by a factor of 2.8.

103.04 — The Next Generation GBT

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The Green Bank Telescope (GBT) is the US astronomical community's only open-skies, large single-dish radio telescope operating from decimeter to millimeter wavelengths. Since its inception, the GBT has been an excellent platform for developing and deploying new technology in support of a broad range of science, including fundamental physics, the transient radio sky, multi-messenger astronomy, star formation, cosmology, planetary science, and the search for life beyond Earth. The Green Bank Observatory (GBO) intends to enhance the capabilities of the GBT in support of the US scientific community. Several of these small to mid-scale projects will include: 1) A growth in the GBT's radio camera program, 2) Using new digital technology to increase instantaneous bandwidth and mitigate the impact of radio frequency interference (RFI), 3) Developing the most sensitive radio receivers, 4) A data archive and scientific tool-kit for large-area surveys, 5) Precision telescope control, 6) Enhancing radio quiet zones, and 7) Advanced monitor and control systems. This poster will discuss these upcoming projects in more detail and will describe how the GBO plans to implement these exciting new capabilities.

103.05 — The 100m Green Bank Telescope

Karen L. O'Neil[1]; Will Armentrout[1]; Amber Bonsall[1]; Natalie Butterfield[1]; David T. Frayer[1]; Frank D. Ghigo[1]; Tapasi Ghosh[1]; Felix J. Lockman[1]; Ryan S. Lynch[1]; Ronald J. Maddalena[1]; Anthony Howard Minter[1]; Larry Morgan[1]; Christopher J. Salter[1]; Andrew Seymour[1]; Joy Nicole Skipper[1]

[1] *Green Bank Observatory (Green Bank, West Virginia, United States)*

The 100-m, filled aperture, Green Bank Telescope operates well between 100 MHz and the atmospheric cutoff at 116 GHz, is equipped with state of the are receivers and detectors, and is located in a region that provides terrain shielding and legal protection from interfering sources. The GBT observes 85% of the entire celestial sphere, and can track an object for the entire time that it is at least 5 degrees above the horizon. It has the ability to switch between diverse instruments in its focal plane in just a few minutes, and can be operated remotely.

The GBT offers "open skies" access for the best peer-reviewed projects and is a training ground for students, something which is increasingly absent from remote astronomical facilities. It can also be used for very long baseline interferometry both with telescopes in Europe and those in the western US, and is prime location for bi-static radar studies from transmitters at the Goldstone and Arecibo facilities.

Current high profile science on the GBT in the next few years includes:

- Bi-static radar studies of objects in the solar system allowing asteroid accurate orbital predictions;
- Spectroscopy of interstellar molecules with an emphasis on organic chemistry, discovering new molecules and understanding their formation mechanisms;
- Wide-field mapping of molecular clouds with a high spatial dynamic range to reveal the conditions for star formation;
- Studies of pulsars and other compact objects, including searches for new pulsars and long term monitoring of pulsars for the detection of gravitational radiation;
- Studies of low surface-brightness 21cm HI emission around galaxies to understand their formation and evolution;
- Making high resolution maps of the Sunyaev-Zeldovich effect in galaxy clusters to show the history of assembly of these most massive objects;
- Long-baseline very high angular resolution studies of active galactic nucleii, accretion disks around black holes, and other phenomena.
- Studying atomic and molecular gas in the Milky Way's central molecular zone and the Fermi Bubble wind;
- Measuring the molecular content of galaxies near and far, to understand how the gas content relates to the formation and evolution of galaxies.

103.06 — A Fast Poisson Solver with Vacuum Boundary Conditions in 3D Cylindrical Coordinates

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In modelling self-gravitating, rotating disks such as massive circumnuclear and protoplanetary disks, it is desirable to employ a fully three-dimensional Poisson solver in a cylindrical geometry subject to the open boundary conditions. We develop an accurate and efficient method for such a solver that works in Cartesian, uniform cylindrical, and logarithmic cylindrical coordinates. Our method consists of two parts: an interior solver and a boundary solver. The interior solver adopts an eigenfunction expansion method together with a tridiagonal matrix solver to solve the Poisson equation subject to the zero boundary condition. The boundary solver employs James's method with the discrete Green's function in order to calculate the boundary potential due to the screening charges required to keep the zero boundary condition for the interior solver. A full computation of gravitational potential requires running the interior solver twice and the boundary solver once. We perform various tests to check that our solver is second-order accurate and exhibits good parallel performance.

103.07 — Astronomical Data Mining with NRAO NINE and UWI Trinidad

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We present work from the NRAO NINE - the National and International Non-traditional Exchange program. NINE aims to broaden participation in radio astronomy and data mining among a diverse group of nations interested in software, hardware, and education development. Workshops at the University of the West Indies at St. Augustine in Trinidad and Tobago utilized Raspberry Pi single-board computers to introduce students to astronomical computing, data mining, and imaging from the NRAO VLA Sky Survey (VLASS). With this low-cost computing solution, we can use Python to manipulate images and catalogs as participants make their first foray into multi-wavelength data mining. The NRAO NINE Program aims to establish active hub institutions so that participants can further expand their skill sets - in the case of UWI the Trinidad Radio Astronomy Community (TRAC) was established. TRAC will expand upon educational opportunities in radio astronomy and computing for UWI and the Trinidad community.

104 — Education & History Poster Session

104.01 — The Role of Observatories in Professional Astronomy Training

Karen L. O'Neil[1]; Will Armentrout[1]; Amber Bonsall[1]; Natalie Butterfield[1]; David T. Frayer[1]; Frank D. Ghigo[1]; Tapasi Ghosh[1]; Felix J. Lockman[1]; Ryan S. Lynch[1]; Ronald J. Maddalena[1]; Anthony Howard Minter[1]; Larry Morgan[1]; Christopher J. Salter[1]; Andrew Seymour[1]; Joy Nicole Skipper[1]; Sue Ann Heatherly[1]
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As we transition further into the era of "big data astronomy," observatories which have traditionally operated as training beds for the country's future astronomers are being crowded out. They are, nevertheless, essential in part as training sites for professional astronomers. The result of this is felt in a number of ways. First, as the pool of astronomers with detailed instrumentation knowledge decreases, the probability of a given astronomer knowing an instrument expert in a given field also decreases. As a result, astronomers become extremely dependent on the quality and accuracy of canned data reduction routines and pre-reduced data which is supplied by the national (and university) telescope facilities. If flaws exist in the routines or data, or if the instrumentation limits are reached within the data, there is an increasing probability that fact will not be realized prior to the data's publication, resulting in the publication of potentially erroneous results. A second, and equally important, consequence is that the national facilities will have an increasing difficulty finding knowledgeable staff to create the required data reduction routines and data products.

Observatories are where textbook theories jump into action. Training the next generation of astronomers how to not only interpret data, but push the limits of what is possible with current telescopes is critical for the advancement of astronomical research. With commitment to and investment in observatory training programs, the state of our profession will be strengthened for the next generation of scientists and engineers. Here we look at three aspects of the necessary training: [1] telescope training, [2] professional advancement, and [3] flexible instrument and software experimentation at observatories.

104.02 — Cal-Bridge: Engaging Underrepresented Students in Physics and Astronomy

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We describe the Cal-Bridge program, which has the mission of increasing participation of groups traditionally underrepresented in physics and astronomy through scholarships, significant mentoring, professional development, and summer research opportunities, creating a national impact on their numbers successfully pursuing a PhD in the field. Now in its fifth year, the Cal-Bridge program is a CSU-UC Bridge program comprised of physics and astronomy faculty from 9 University of California (UC), 16 California State University (CSU), and more than 30 California Community College (CCC) campuses throughout California. Cal-Bridge provides mentoring and professional development experiences over the last two years of undergraduate and first year of graduate school to students from this diverse network of higher education institutions. Cal-Bridge Scholars benefit from substantial financial support, intensive, joint mentoring by CSU and UC faculty, professional development workshops, and exposure to research opportunities at the participating UC campuses. In addition, they are given summer research opportunities through the Cal-Bridge summer research program (formerly known as CAMPARE). A subset of CAMPARE scholars participate in a program called CHAMP (CAMPARE-HERA Astronomy Minority Partnership) in collaboration with the HERA radio telescope consortium. In the first five years, 59 Cal-Bridge Scholars have been selected, including 34 Latinos, 7 African-Americans and 25 women (15 of the 25 women are from underrepresented minority groups). Forty-four (44) of the 59 Cal-Bridge Scholars are first-generation college students. In the first 4 years, 27 of 34 Cal-Bridge Scholars have begun or will be attending PhD programs in physics or astronomy at top PhD programs nationally. The others are attending Master's-to-PhD Bridge programs, Master's Programs in physics or astronomy, or in one case, teaching high school physics. Five (5) scholars have won NSF Graduate Research Fellowships and three more received an Honorable Mention in the first 3 years of the program. Funding for these programs is provided by NSF-DUE SSTEM Grants #1356133 and #1741863, NSF-AST PAARE Grant #1559559, and NSF AST MSIP Grant #1564352.

104.03 — Orchestar: Teaching the Color/Temperature Relation through Sound

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The relation between color and temperature is one of the fundamental concepts of an introductory astronomy course. However, for non-visual learners, the association – which is typically taught with visual aids – can be difficult to make. Using the process of "sonification," an Arduino-based device has been developed at Harvard University to convert color to sound with an RGB color sensor and MIDI board. The device, known as Orchestar, is able to sonify both reflected and transmitted light and is intended to be used as a tool for teaching the color/temperature relation, both in a laboratory setting and on a telescope. The documentation and code for Orchestar, which costs around $90 to build, is freely available online so that others may build their own (and modify the code, if they wish).

104.04 — From Clouds to the Stars: the History of the Magdalena Ridge Observatory Interferometer

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This paper presents the history of the development of the Magdlena Ridge Observatory Interferometer which started with the cloud studies carried out on Magdalena Ridge in South Central New Mexico during the 1930's. By the 1960's these studies had grown to such an extent that they warranted the creation of the Langmuir Atmospheric Laboratory - named for eponymous Nobel laureat. Although Langmuir had never worked in the Magdalena mountains the laboratory named in his honor was in 1975 was the recipient of the residue of his estate.

However, other pioneers of science did work on Magdalena Ridge, including Charles Moore who ascended in a balloon into the heart of a thundercloud and Stirling Colgate who in 1973 oversaw the establishment of the double telescope Joint Observatory for Cometary Research (JOCR) and in the following year established a digital supernovae telescope on the Ridge.

The existence of this astronomy observatory on Magdalena Ridge led in 1995 to the gift to New Mexico Tech of a declassified 2.4-meter primary mirror, originally intended for space surveillance. In turn this led to the design of a 3-element optical interferometer to be installed on what by now had been named Magdalena Ridge Observatory. By the year 2004, following the signing of a memorandum of agreement with the University of Cambridge in 2002, the 3-element array had been redesigned as an array of 10 x 1.4-meter optical telescopes to be the first of the the generation of sparse array optical interferometers.

It is suggested that in terms of relative resolution and sensitivity the Magdalena Ridge Observatory Interferometer (MROI) will arguably be the most powerful optical telescope on earth; with even greater resolution than the Hubble Space Telescope (HST) and also greater than that of the three much hyped 30-meter class telescopes that are currently in development (ELT, TMT, GMT). The sensitivity of the MROI also far exceeds (by a factor of 10 to 100 times) that of other high resolution interferometers such as CHARA, NPOI and the European VLTI.

105 — Extrasolar Planets Poster Session

105.01 — Imaging the Interaction between Planets and Young Disks with the ngVLA

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The recent discovery of thousands of protoplanetary disks and exoplanets has revealed that planet formation is a very efficient process in nature. There have been several theories to describe the many steps along this process, but it remains difficult to discover planets surrounding young stars. Thanks to its unprecedented angular resolution and sensitivity at wavelengths where the emission from the circumstellar material is optically thin, the future ngVLA telescope has the potential to transform our understanding of planet formation. In this presentation I will highlight the unprecedented imaging capabilities of the ngVLA using theoretical models of protoplanetary disks. These images will help shed light on how planets interact with disks and young stars, as well as on the properties of forming exoplanetary systems.

105.02 — A Survey of the Habitability of TESS Planet Candidates

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The Transiting Exoplanet Survey Satellite (TESS) has so far discovered a multitude of potentially habitable planet candidates. The next step in confirming the habitability of these exoplanets will be spectroscopic observations by the next generation of telescopes. In an effort to prioritize candidates for these observations, I have calculated the Earth Similarity Index (Schulze-Makuch, D. et al., 2011) for each of the planet candidates identified by TESS that are within the habitable zones of their host stars. As TESS data is based on transit observations and not radial velocity measurements, the density of the planets used in the calculations is obtained using the mass-radius relationship created by Ning, B. et al. (2018) which in turn is based on data taken from the Kepler mission. Overall, 3 were found to have a global ESI greater than 0.8, indicating an Earth-like planet, though 11 had global ESIs between 0.7, the ESI of Mars and 0.8.

105.03 — Linking the properties of protoplanetary disks and their host stars in the Taurus region

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Protoplanetary disks are dense regions of gas and dust rotating around a young T Tauri star. As the name suggests, protoplanetary disks are where planets form. These disks can also serve as accretion material for the young central star. In this project we aim to study about 100 protoplanetary disks in the Taurus-Auriga young star forming region. The main focus of our study is the relationships between the spectral index, fluxes at mm-wavelengths and stellar properties, as well as the correlation between the mass of the central star and the mass of dust in the protoplanetary disk. Disk masses are inferred using previous flux observations in 0.89 mm and 1.33 mm wavelengths, as well as recent observations at a wavelength of 3 mm using The Combined Array for Research in Millimeter-wave Astronomy (CARMA). This study will allow us to refine scaling laws linking disk and stellar properties, and shed light on the origin of some of the key scaling laws recently observed from the known population of exoplanets.

105.04 — Direct Detection of CO in CI Tau b: Support for Hot Start Formation

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We analyze high resolution IR spectra of CI Tau, the host star of one of the few young planet candidates amenable to such observations. We confirm the planet's existence with a direct detection of CO in the planet's atmosphere. We determine a mass of 11.6 Mjup based on the amplitude of the planet's radial velocity variations. We estimate the planet's flux contrast with its host star to obtain an absolute magnitude estimate for the planet of 8.17 in the K band. This magnitude implies the planet formed via a "hot start" formation mechanism. This makes CI Tau b the youngest confirmed exoplanet as well as the first exoplanet around a T Tauri star with a directly determined, model-independent, dynamical mass.

105.05 — Formation of Satellites Around the Outer Planets of the Trappist-1 System

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The Trappist-1 system (Gillon et al. 2017) is a compact configuration of seven Earth-like planets orbiting a M-type dwarf star. The presence of moons cannot be confirmed in the transit data. Orbital parameter instabilities in the Trappist-1 system are known and the timescales of these instabilities have been determined (Burgasser & Mamajerk 2017). Previous work by Allen, Becker, & Fuse (2018) found that some Trappist-1 planets may be able to retain a single satellite through at least the duration of the planetary instability. The current study examines the formation and stability of satellites around the outer planets Trappist-1f, g, and h. Moon disks are simulated by distributing 100 bodies, each with mass 5.26 x 10^{18} kg randomly within 10% - 90% of the exoplanet's Hill sphere. Utilizing N-body simulations, the planets and theoretical moons were tracked for 500 kyrs, allowing for gravitational interactions and mergers.

105.06 — Dust Evolution in the Late Stages of Planet Forming Disks

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We study the properties of dust in disks to constrain models of planet formation. We analyze the spectral index for the dust continuum emission at millimeter wavelengths for 24 young disks in the Upper Sco star forming region. We do this by combining data taken with the ALMA telescope at wavelengths of 2.87 mm and 0.88 mm. Since the age of this region is $\sim$ 5 - 10 Myr, these results can constrain the properties of small solids in disks at the end of their lifetime. We examine whether pebble trapping, which is key to planet formation, happens only in much younger disks or if it is efficient all the way towards the end of the disk life cycle. If the latter is true, planetesimals could still form despite the low gas densities in the disk at the end of its life cycle. In the case of the opposite scenario, our results would indicate that radial drift takes over the dynamical evolution of dust towards the end of the disk lifetime.

106 — Solar Physics Division (SPD), Poster Session I

106.01 — Multi-line diagnostics of the coronal magnetic field with DKIST

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Full-stokes polarimetric observations of multiple coronal emission lines can in principle be used to infer the vector magnetic field in the solar corona assuming the emission is all coming from a single location in space. The Fe XIII line pair at 10747 / 10798 Å has already been identified as a prime candidate for multi-line inversions; although such measurements are sensitive to uncertainties and biases that must be carefully assessed. That said, this technique may have additional utility when expanded to other multi-line observations planned for the National Science Foundation's Daniel K Inouye Solar Telescope (DKIST). This work investigates, in particular, the use of the Fe XIII 10747 / Si X 14301 Å line pair, and its benefits for probing the magnetic conditions in cooler coronal loops formed near 1.4 MK. We discuss the advantages and limitations of the Fe XIII / Si X line pair as well as possible observing scenarios with the DL-NIRSP and Cryo-NIRSP instruments on the DKIST.

106.02 — Multiscale Helicity Condensation and Filament Channel Formation

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Solar eruptive events ranging from small-scale jets to global-scale coronal mass ejections are associated with filaments and their underlying filament-channel magnetic structures. In previous work, we have demonstrated that sheared-arcade filament channels can be formed via the process of helicity condensation. Magnetic twist, representing helicity, is transported across unipolar regions in response to reconnection induced by small-scale, close-packed, surface flows (e.g., the granulation or supergranulation) that possess a vortical component of motion. The small-scale twists induced by the flows inverse-cascade to the largest scales and boundaries of the unipolar regions, i.e., to the polarity inversion lines (PILs). If the flows have a preferred sense of rotation, clockwise or counter, they inject a net helicity into the magnetic field, as well as transport it so that it condenses into filament channels at the PILs. We now have examined how the helicity condensation mechanism is modified when the small-scale flows have no preferred sense of rotation, and large-scale flows are solely responsible for introducing net helicity into the corona. On the Sun, differential rotation is well-known to be a prodigious generator of helicity. Our new simulation results show that a large-scale shear flow produces structure with large-scale magnetic twist, but this twist concentrates near the PILs to form filament channels only when small-scale vortical flows also are present. We conclude that the key role of the vortical flows is to transport the injected net helicity and condense it at the PILs. The source of the net helicity, on the other hand, can be flows at any scale. We refer to this extended concept as multiscale helicity condensation: it is a more general, hence more robust, explanation for the formation of filament channels on the Sun. Our work was supported by NASA's H-ISFM, H-SR, and LWS TR&T programs.

106.03 — Invisibility of Solar Active Region Umbra-to-Umbra Coronal Loops: New Evidence that Magnetoconvection Drives Solar-Stellar Coronal Heating

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How magnetic energy is injected and released in the solar corona, keeping it heated to several million degrees, remains elusive. The corona is shaped by the magnetic field that fills it and the heating of the corona generally increases with increasing strength of the field. For each of two bipolar solar active regions having one or more sunspots in each of the two main opposite-polarity domains of magnetic flux, from comparison of a nonlinear force-free model of the active region's three-dimensional coronal magnetic field to observed extreme-ultraviolet coronal loops, we find that (1) umbra-to-umbra loops, despite being rooted in the strongest magnetic flux at both ends, are invisible, and (2) the brightest loops have one foot in a sunspot umbra or penumbra and the other foot in another sunspot's penumbra or in unipolar or mixed-polarity plage. The invisibility of umbra-to-umbra loops is new evidence that magnetoconvetion drives solar-stellar coronal heating: evidently, the strong umbral field at both ends quenches the magnetoconvection and hence the heating. Broadly, our results indicate that depending on the field strength in both feet, the photospheric feet of a coronal loop on any convective star can either engender or quench coronal heating in the body of the loop.

This work was supported by funding from the Heliophysics Division of NASA's Science Mission Directorate, from NASA's Postdoctoral Program, and from the Austrian Science Fund. The results have been published in The Astrophysical Journal Letters (Tiwari, S. K., Thalmann, J. K., Panesar, N. K., Moore, R. L., & Winebarger, A. R. 2017, ApJ Letters, 843:L20).

106.04 — Revisiting Taylor relaxation

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Turbulent magnetic relaxation is an important candidate mechanism for coronal heating and some types of solar flare. By developing turbulence that reconnects the magnetic field throughout a large volume, magnetic fields can spontaneously self-organize into simpler lower-energy configurations. We are using resistive MHD simulations to probe this relaxation process, in particular to test whether a linear force-free equilibrium is reached. Such an end state would be predicted if one were to assume the classic Taylor hypothesis: that the only constraints on the relaxation come from conservation of total magnetic flux and helicity. In fact, a linear force-free state is not reached in our simulations, despite the conservation of these total quantities. Instead, the end state is better characterised as a state of (locally) uniform field-line helicity.

106.05 — Characteristics of ephemeral coronal holes

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Small-scale ephemeral coronal holes may be a recurring feature on the solar disk, but have received comparatively little attention. These events are characterized by compact structure and short total lifetimes, substantially less than a solar disk crossing. Following a search of the time period 2010 - 2015 using Atmospheric Imaging Assembly EUV image data from the Solar Dynamics Observatory, we present analysis of four of the clearest examples of the ephemeral coronal hole phenomenon. The properties of each event are characterized, including their total lifetime, growth and decay rates, and areas. The magnetic properties of these events are also determined using Heliospheric Magnetic Imager data. These ephemeral coronal holes possess common characteristics, experiencing rapid initial growth of up to $\sim$3000 Mm^2 / hr, while the decay phases are typically more gradual. Like conventional coronal holes, the mean magnetic field in each ephemeral coronal hole displays a consistent polarity, with mean fields generally < 10 G. No evidence of a corresponding signature is seen in solar wind data at 1AU. Further study is needed to determine whether ephemeral coronal holes are under-reported events or a truly rare phenomenon.

106.06 — Forward Models of Off-Limb Emission Lines in Solar Coronal Holes

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There is debate in the solar community regarding the mechanism by which the corona is heated to millions of degrees. Alfvén waves, driven by granulation in the photosphere and propagating upwards to dissipate in the corona, are one of several ideas for the source of the thermal energy. Observations of off-limb spectral lines are in theory able to constrain some properties of these waves (e.g., amplitudes and phase speeds) as a function of heliocentric altitude, but in practice the interpretation of these measurements is difficult due to the optically-thin nature of the corona. In this work, a forward model (GHOSTS) is developed and refined so that it can be used to generate realistic simulated observations of these lines. Recent improvements to the model include the addition of resonantly scattered light and the self-consistent calculation of frozen-in non-equilibrium ionization states. Early results indicate that the non-thermal widths of these lines seem to be significantly broadened by the presence of the solar wind, even as close to the Sun as a few tenths of a solar radius. We also aim to put constraints on the cadence and integration times needed to resolve individual Alfven-wave oscillations, as have been seen with CoMP.

106.07 — Constraining CME Mass in HI-1

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Mass is an important parameter in both the physical processes which govern CME motion and is directly linked to CME observations, as most remote sensing measurements of a CME are white-light images where intensity is correlated with density. As such, mass is both a crucial parameter to measure and one of the few that can be studied directly. Most attempts to determine masses from remote sensing data have focused on coronagraph data, where the CME is bright and still a roughly self-similarly expanding flux rope that has undergone few dynamic changes since the initial eruption. However, to understand the flux rope evolution once the CME begins to interact with the upstream solar wind and determine how it may change in the heliosphere, it is necessary to probe the data and constrain the mass at higher heights. Attempts to extend the coronagraph methods and study the mass at higher heliographic distances have been difficult given the low signal to noise ratio of CME observations in the STEREO SECCHI HI-1 FOV. This study uses improved image processing techniques to better isolate the ejecta mass from the background. Obtaining this signal without resorting to running-difference techniques reduces the amount of useful signal lost due to image processing while still reducing the unwanted contribution from stars and other background features. By comparing the obtained masses with both COR2 measurements as well as in-situ densities we can better understand the challenges in determining mass farther away from the Sun and quantify the systematic error such an approach introduces. Directly studying more local evolution of the mass inside the CME, we can directly address the degree to which the CME evolves non-uniformly and how momentum is transferred between the CME and the upstream solar wind.

106.08 — Adding RESTful web services to the VSO: How to write Data Providers in Python

Edmund Mansky[1]
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Adding support for RESTful web services to the VSO codebase is described. The ability to query Data

Providers as RESTful web services generalizes the VSO so both SOAP and REST data transfer techniques are supported. The requirements of adding queries to remote RESTful services from a multi-threaded Perl application is detailed. Examples of RESTful Data Providers written in Python, using the Flask and Django frameworks are provided. The two primary Data Providers illustrated are the new Parker Solar Probe and the existing EUNIS re-written as a Python Data Provider. Automatic validation of the RESTful service, in both Perl and Python is examined. Use of unit tests in Python and load testing using Locust is also detailed. The steps needed to write new RESTful Data Providers in Python are presented.

106.09 — Alfvén waves propagating in an inhomogeneous plasma similar to those in coronal holes

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Alfvén speed gradients in directions parallel and perpendicular to the ambient magnetic field in coronal holes are thought to aid dissipation of wave energy and thus contribute to coronal heating. We have studied Alfvén wave propagation under conditions similar to coronal holes in the Large Plasma Device located at University of California, Los Angeles. The energy of Alfvén waves propagating in the presence of an Alfvén speed gradient perpendicular to the ambient magnetic field is observed to spread to higher $k_\perp$. This spreading of energy is more prominent for steeper gradients and larger $z/\lambda_\parallel$, where z is the distance away from the antenna, and $\lambda_\parallel$ is the wavelength parallel to the ambient magnetic field. Our initial analysis shows that spreading of wave energy to higher $k_\perp$ may enhance the rate of dissipation of wave energy. However, additional experiments are necessary to confirm plasma heating. Alfvén waves propagating through an Alfvén speed gradient parallel to the ambient magnetic field are observed to lose five times more energy than they do when propagating through the same distance in the absence of a gradient. This reduction in wave energy is observed to increase monotonically with an increase in $\lambda_\parallel/L_{A,\parallel}$, where $L_{A,\parallel}$ is the scale length of the Alfvén speed gradient parallel to the magnetic field. The cause of this reduction in energy is constrained by ruling out reflection, mode conversion and nonlinear effects. Since, the total energy must be conserved, it is possible that the reduced wave energy is deposited in the plasma. Further experiments are necessary to confirm if this wave energy contributes to plasma heating.

106.10 — A Total Solar Eclipse Observing Tool to Advance Coronal Heating Knowledge and Bolster Authentic STEM Undergraduate Research Experiences

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A formidable solar physics challenge is describing the magnetic-to-radiative energy coupling of the Sun's atmosphere. Total solar eclipses provide a rare opportunity to advance our knowledge of solar atmospheric energy redistribution processes, as the structure, distribution, and dynamics of coronal magnetic fields, as well as the emission spectrum of the chromosphere can be directly observed. We built the Solar Eclipse Observing Package (SEOP) as a tool for pc control of linear polarizing, white light, and flash spectrum digital camera systems to advance our knowledge of coronal heating by observing the August 21st 2017 total solar eclipse. Last minute cloud cover unfortunately kept our expedition from observing totality of this eclipse. However, during the months, and up to the last minutes leading to its totality, the computer, engineering, and coronal physics science behind our team's SEOP, imaging systems, and scientific objectives were disseminated through a number of educational engagements and outreach activities. Plans are now underway to observe the next total solar eclipse to cross the continental United States in April 2024.

Funding Sources: University of the Virgin Islands, OrangeWave Innovative Science, LLC, St. Thomas Astronomy Resource Society, and the US Department of Agriculture.

106.11 — Community Input Solicited for Heliophysics Decadal Survey Midterm Assessment Committee

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The National Academies of Sciences, Engineering, and Medicine has convened a committee to review the progress towards implementing the 2013 Heliophysics Decadal Survey, titled *Solar and Space Physics: a Science for a Technological Society*. This review serves as a midterm assessment before the next Heliophysics Decadal Survey committee would begin its formulation. This committee is interested to receive input from the heliophysics and space weather communities about the 2013-2018 progress realizing the 15 recommendations and applications specified in the 2013 Heliophysics Decadal Survey, about any suggested actions to optimize the science value during 2019-2023, about any suggestions to improve the process for the next Heliophysics Decadal Survey, and about any suggested actions to enhance all stages of careers for scientists and engineers in the solar and space physics community. This poster will outline the Heliophysics Decadal Survey recommendations and recent progress, and it will also summarize the tasks for this midterm assessment committee. There will be an opportunity to discuss your inputs with a couple of the Committee members during the AAS/SPD meeting, and web-based community-input survey opportunities are anticipated to be available soon.

106.12 — Optical Alignment of DL-NIRSP Spectrograph

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The Diffraction-Limited Near-Infrared Spectropolarimeter (DL-NIRSP) will be delivered as part of the first light instrumentation for the Daniel K. Inouye Solar Telescope (DKIST) and is currently undergoing lab integration at the University of Hawai'i Institute for Astronomy's Advanced Technology Research Center on Maui. An off-axis hyperbolic mirror, with a focal length of 1250 mm, is used as both collimator and camera in the spectrograph, and makes this system particularly difficult to align. The optical axis, or vertex, of the parent surface is located approximately 260 mm from the center of the off-axis section of the mirror, but there is no direct physical or optical reference for the location and orientation of the optical axis. We have made use of vendor data and a coordinate measuring machine (CMM) arm to transfer coordinates from the back and perimeter surfaces of the mirror to locate the optical axis focus and place the other optical components in reference to this mechanical model. In coordination, we have conducted tests of the optical quality at various points during the alignment to ensure that the mechanical tolerances maintain the optical quality of the system so that the instrument will be able to achieve excellent spectral resolution limited by the spectrograph slit width ($\lambda/\Delta\lambda \sim 250{,}000$), and preserve the diffraction limited spatial resolution provided by the telescope and feed optics (0.06″ at 1 μm).

106.13 — A Makeover for HMI Magnetic Field Data

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HMI, the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory (SDO) has measured the Sun's vector magnetic field nearly every 135 or 90 seconds since May 2010. The Stokes parameters are determined from sets of filtergrams every 720 seconds over the full disk. The quality of the images is remarkably uniform and the measurements are reliable for many types of analysis. However, the inverted and disambiguated magnetic field values are occasionally incorrect, show small periodic variations with time and spacecraft velocity, or depend in a systematic way on disk position or magnitude. Estimates of uncertainties in the inversion are provided for each point, but for some kinds of analysis having a smoother and more uniform time series is necessary.

Sources of some errors are well understood and well characterized, but others are not. Statistical and empirical techniques have been developed by the HMI Team and others to improve both the calibration and appearance of the observations, to increase consistency, and minimize undesirable variability. Effects addressed include issues related to field inversion, disambiguation, sensitivity, optical distortion, instrument characteristics, and systematic errors due to spacecraft velocity and viewing angle. Some of the most reliable and affordable corrections are included in the regular analysis pipeline. Some corrections are too compute intensive to implement routinely. For others the resulting 'corrections' depend on assumptions about the typical behavior of the solar magnetic field, so care must be taken when using such results.

106.14 — Solar Polar Observing Constellation (SPOC): A New Age for Solar Observations

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Current observing platforms can only measure the solar magnetic field over a portion of the Earth-facing hemisphere, forcing us to rely on solar rotation to build up fictional "synoptic maps" of the full-Sun field over 27-days. The lack of magnetic field "boundary conditions" over the full Sun represents a fundamental gap in our ability to accurately model the solar coronal magnetic field and solar wind acceleration. Views restricted to the ecliptic plane cannot capture the Sun's polar regions. Observation of the poles from a high latitude vantage point are needed to advance helioseismology and constrain the Sun's polar fields and high latitude flows, which are crucial to understanding the solar activity cycle. Furthermore, sustained observation of the Sun's polar regions will enable helioseismology investigations of the polar subsurface flows, allowing us to probe deeper into the mechanisms of the solar cycle.

We propose a novel constellation of small satellites called the Solar Polar Observing Constellation (SPOC) that will obtain magnetic field and doppler velocity measurements from a solar polar orbit, including nearly direct overhead measurements of the poles. The SPOC constellation consists of two identical satellites placed into ~90-degree inclination heliocentric orbits using Jupiter gravitational assist (JGA) trajectories and ion electric propulsion to circularize the orbit at about 0.9 AU. Instrumentation includes a compact helioseismic magnetic imager, compact coronagraph, and in-situ solar wind plasma measuring instruments. The SPOC mission follows the model of "hybrid operational-research" missions developed by the CU Space Weather Technology, Research, and Education (SWx-TREC) to enhance utility and collaboration by developing critical operational data sources for space weather forecasting that can also produce exploratory science data.

106.15 — 3D Realistic Modeling of Chromospheric and Coronal Heating and Self-Organization

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Turbulent magnetoconvection is a primary driver of the dynamics and structure of the solar atmosphere and corona. Realistic high-resolution radiative MHD simulations reveal a complex multiscale structuring and dynamics above the photosphere. We present a detailed study of dynamical links between small-scale magnetic fields generated by local dynamo action and properties of the chromosphere and corona, as well as effects of coherent self-organized magnetic structures. In particular, we discuss formation of coherent structures, eruptive dynamics, and contributions of multi-scale structuring and highly non-linear dynamics to heating of the chromosphere and corona.

106.16 — Homologous Coronal Mass Ejections and Their Precursor Phase

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We present the study of three homologous solar eruptions from the AR 11429. These eruptions occurred at different evolutionary phase of the AR i.e. emergence and decay phase of the magnetic flux. It was a big and complex AR and could be divided into two sub-regions, namely north-east (NE) and south-west (SW). We found that there was continuous injection of magnetic helicity and energy flux in the AR. Further, we observed continuous shearing motion of the magnetic flux, converging motion of the opposite magnetic polarity, and magnetic flux cancellation in the SW sub-region. We believe that these physical processes were continuously adding helicity and energy into partially erupted magnetic system and were responsible for the formation of identical erupting structures along the same polarity inversion line (PIL). A small confined flare was observed, at the left side of SW sub-region, during the precursor phase (PP) of each homologous eruption. It was identified as peak in soft X-ray (SXR) intensity profile, brightening of hot-channel structure (HCS), and appearance of flare ribbon below the HCS. Using the results of Non Linear Force Free Field (NLFFF) model we studied the magnetic topology of the SW sub-region. The magnetic topology of the AR was stable and persistent during the evolution of the AR, therefore flare during the PP was observed around the same location. Our study suggests that the PP-flare facilitate the eruption of magnetic structure, lying along the SW-PIL, by weakening the overlying magnetic pressure. We also think that the continuing flux cancellation along the SW-PIL repeatedly re-produced a twisted magnetic flux rope following each eruption.

106.17 — Three-dimensional Reconstruction of CMEs and Observational Constraints of Measured Parameters

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This study focuses on the early evolution and propagation of coronal mass ejections (CMEs) close to the Sun. We are tracking the evolution of both the ejecta and its shock . We focus on CMEs that were observed during the period 2010-2012 and in this study we present four of them. Events that occurred close to the disc center as viewed from Earth are observed as limb events from the two STEREO spacecraft and that gives us the opportunity to reconstruct their three dimensional structure. We are using the graduated cylindrical shell (GCS) model to fit the ejecta and the 3D spherical shell model to fit the shock with white light data from three viewpoints separated by about 90 degree from each other. Thanks to three viewpoints of observations, we are able to constrain parameters like the aspect ratio of the ejecta (cross section size) and its shock (radius) as well as the tilt angle, which we find are difficult to constrain with two viewpoints of observations. Being able to constraint those parameters can lead to a better understanding of the morphology and evolution of CMEs and help the prediction of space weather. The ability to have accurate predictions is closely related to monitoring the Sun from multiple viewpoints, i.e., three or more, which implies a need of multi-spacecraft mission in the future.

107 — iPoster Session: Solar Physics Division (SPD), Session I

107.01 — Cross calibration for coalignment, Hinode/SOT, IRIS, and SDO

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Yoshimura and McKenzie (Solar Physics, vol.290, p.2355, 2015) reported the results of the successful cross calibration for the coalignments between the X-Ray Telescope (XRT) onboard Hinode and two instruments onboard Solar Dynamic Observatory (SDO), i.e., the Helioseismic and Magnetic Imager (HMI) and the Atmospheric Imaging Assembly (AIA).

We are extending the same calibration methods to other instruments, which include: (1) the Interface Region Imaging Spectrograph (IRIS), (2) the Solar Optical Telescope (SOT) onboard Hinode, and (3) AIA/HMI.

We summarize the modification and optimization of the methodology and present the results of the calibrations. Time variation of the roll angles and the plate scales will be discussed. The results can be used for better coalignment.

We have also done the calibration between different wavelengths of SOT filtergram data. After the corrections using the calibration results, we can still see some offsets between the different wavelength images which vary with the position of the observing region on the solar disk. We attribute this to the differing heights of formation associated with each wavelength band.

107.02 — A Statistically-Validated Approach for Flux Emergence Identification

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We present a new method for automatically identifying events of magnetic flux emergence in time series of magnetograms of the sun. Despite their obvious and striking visual appearance, these events can be surprisingly difficult to identify with high specificity and sensitivity. Because of the broad range of spatial and temporal scales across which emergence occurs, as well as a host of physical, geometrical, numerical, and sometimes operational considerations, accurate detection has been difficult to implement. In this presentation, we describe our technique, developing a logistic regression model based on thresholds of user-defined quantities such as signed and unsigned magnetic flux in a region, the time derivative of those quantities, etc. A backward stepwise approach is used to find the best predictors of magnetic flux emergence, and the score cutoff chosen to maximize the paired sensitivity and specificity. The final model is evaluated using the area under the Receiver-Operator-Characteristic (ROC) curve. We describe the performance of the method, highlighting events for which a successful detection is made, missed, or falsely identified.

107.03 — Listening to the Sun

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How many ways can we explore the Sun? We have images in many wavelengths and squiggly lines of many parameters that we can use to characterize the Sun. We learn that the Sun is bright with regions that are dark in some wavelengths and bright in others. But those classifications are both based on vision. Sound is another sense to use in exploring solar data. Some data, such as the sunspot number or the extreme ultraviolet spectral irradiance, can be easily sonified. Images are more difficult. A simple raster scan is dominated by moving on and off the limb of the Sun. Any sonification of the raster scan will contain discontinuities at the limbs that mask the information contained in the image. We propose to sample the curves with Hilbert curves to reduce those discontinuities. Hilbert curves are continuous space-filling curves that map the two-dimensional coordinates of an image onto a linear variable. We have investigated using Hilbert curves as ways to sample and analyze solar images. Reading the image along a Hilbert curve keeps neighborhoods close together as the resolution (i.e., the length of the Hilbert curve) increases. It also removes most of the detector size periodicities and actually shows the presence of longer-scale features. We shall provide several examples of sonified solar data, including the sunspot number, a selection of EUV spectral irradiances, an AIA 171 image, and a series of images during a solar flare.

107.04 — Ultrahigh-Resolution Imaging of the Solar Corona using a Distributed Diffractive Telescope

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Several observational and theoretical considerations suggest that energy is often released in the solar corona on small spatial scales of order 100 km. It has been a longstanding goal of solar physics to subject this hypothesis to direct observational test. However, extreme ultraviolet (EUV) and soft x-ray (SXR) telescopes rarely approach diffraction-limited performance because conventional reflective optics of adequate size typically cannot be manufactured to the requisite figure accuracy. Diffractive optics can overcome the angular-resolution limitations of EUV/SXR mirrors. We describe a mission approach that employs diffractive optics and small satellites flying in formation to form a distributed solar telescope operating at EUV wavelengths.

107.05 — Laboratory measurement of large-amplitude whistler pulses generated by fast magnetic reconnection

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We present observations of large-amplitude ($\delta B/B \sim 0.01$) oblique whistler wave pulses generated by spontaneous, 3D magnetic reconnection in the Caltech jet experiment. The wave pulses are measured far from the reconnection location using a multicluster B-dot probe with a tetrahedral arrangement, mimicking the formations of the Cluster and Magnetospheric Multiscale Mission spacecraft. These pulses are confirmed to be whistler modes by measurements of the background parameters, the wave polarization, and the wave dispersion. The results demonstrate that impulsive reconnection events can generate large-amplitude oblique whistler wave pulses. This provides a new generation mechanism for magnetospheric whistler pulses and may help explain relativistic particle acceleration in other systems with impulsive magnetic reconnection such as solar flares.

107.06 — Radio Propagation Diagnostics of the Inner Heliosphere in the Era of the Parker Solar Probe

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The solar wind offers and extraordinary laboratory for studying turbulence, turbulent dissipation, and heating. The Parker Solar Probe (PSP) was launched in August 2018 to study these and other important processes in the inner heliosphere. One type of observation that will complement those of PSP are ra-

dio propagation measurements of solar wind turbulence in the outer corona and the inner heliosphere. This type of observation can provide measurements of the angular broadening of distant spatially coherent background sources that transilluminate the foreground solar wind plasma. This well-known technique can be used to measure the spatial spectrum of electron density inhomogeneities in the solar wind on scales of 100s of meters to 10s of kilometers inside of 10-15 solar radii over a wide range of position angles.

Here we report the results of a pilot study of background sources using the Jansky Very Large Array (JVLA) in summer 2015. Unlike previous studies of this kind, the JVLA's much greater sensitivity allows fainter and more numerous sources to be used as probes of the foreground medium. We observed 11 background sources in 16 sessions at apparent radial distances of 2-7 solar radii. We confirm previous findings: that the spectrum is flatter than Kolmogorov and that is highly anisotropic. Unlike previous studies we find breaks into steeper spectra for some sources on short spatial scales, suggestive of a transition to dissipation.

Looking forward, we describe observations planned in August 2019 in support of the third PSP perihelion passage (35.7 solar radii). The VLA will be used to observe the corona and inner heliosphere along ~70 pierce points <10 solar radii. These observations will not only provide global context about the state of the inner heliosphere at time of perihelion passage, they will also baseline key solar wind parameters that can be compared directly with PSP measurements. These include turbulence level, spectral index, degree of anisotropy, and the orientation of the magnetic field. The PSP measurements will, in turn, provide measurements that will validate key assumptions made in interpreting the radio data.

107.07 — AWARE: An algorithm for the automated characterization of EUV waves in the solar atmosphere

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Extreme ultraviolet (EUV) waves are large-scale propagating disturbances observed in the solar corona, frequently associated with coronal mass ejections and flares. They appear as faint, extended structures propagating from a source region across the structured solar corona. Since their discovery, over two hundred papers discussing their properties, causes and physical nature have been published. However, despite this their fundamental properties and the physics of their interactions with other solar phenomena are still not understood. To further the understanding of EUV waves, we have constructed the Automated Wave Analysis and REduction (AWARE) algorithm for the measurement of EUV waves. AWARE is implemented in two stages. In the first stage, we use a new type of running difference image, the running difference persistence image, which enables the efficient isolation of propagating, brightening wavefronts as they propagate across the corona. In the second stage, AWARE detects the presence of a wavefront, and measures the distance, velocity and acceleration of that wavefront across the Sun. The fit of propagation models to the wave progress isolated in the first stage is achieved using the Random Sample and Consensus (RANSAC) algorithm. AWARE is tested against simulations of EUV wave propagation, and is applied to measure EUV waves in observational data from the Atmospheric Imaging Assembly (AIA). We also comment on unavoidable systematic errors that bias the estimation of wavefront velocity and acceleration. In addition, the full AWARE software suite comes with a package that creates simulations of waves propagating across the disk from arbitrary starting points.

108 — iPoster Session: Dust & Star Formation

108.01 — Differential abundance techniques applied to iron in two mid-F stars

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We explore and extend the technique of precision abundance differences to the mid-F domain, deriving iron abundance differences between θ Scl (F5 V), and Procyon (F5 IV-V) using UVESPOP spectra (Bagnulo, et al. ESO Messenger 114, 2003). The spectra have resolving power of 80,000. S/N ratios measurements are in agreement with Bagnulo et al. (300-500). We report results for 35 Fe I and 24 Fe II weak and moderate lines (4.3-90mÅ), measured independently by the authors, using Voigt (CRC), and Gaussian (KY) profiles. The mean difference (CRC-KY) for the Fe I lines was 1.26mÅ ± 0.25mÅ (se). Abundances were based on Atlas9 models (Castelli and Kurucz, IAU Symp. 210, 2003), Te=6550 for both stars, log(g)=3.71 & 4.2, Vt=2 & 1.5 km/s, respectively for Procyon and θ Scl. In principle, pairwise abundance ratios are independent of gf values, but for stronger lines saturation must be precisely taken into account. We explore departures from the weak-line approximation. For example, the 26.2 mÅ line Fe I 5247.05 in Procyon would be larger by a factor of 1.28 (0.11 dex) if it were unsaturated. Discrepancies of this nature depend on the state of ionization and excitation of the line and especially the microturbulence. We examine the effect of assuming that the average of the logarithms of abundances may/should be used in place of the logarithm of the averages. For example, the average abundance logarithms for our 24 Fe II lines in Procyon is -4.5820, and in θ Scl is -4.6108. The difference is 0.0288. If we take abundance quotients (not logs) for each line pair (θ Scl/Procyon) the average is 1.09214, whose logarithm is 0.0383. The difference is 0.0383-0.0288=0.0095–not trivial for precision abundances. We use abundance quotients, and then take logs. The mean abundance differences of log(θ Scl/Procyon) for Fe I and Fe II respectively were +0.0528 ± 0.0086 (se), 0.0511 (sd) and +0.0383 ± 0.0189 (se). 0.0927 (sd). The standard errors (se) are in the 0.01-0.02 dex range. There is no significant difference in the iron abundance of these two stars.

108.02 — A massively non-LTE model atmosphere for Sirius A

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Elemental abundances in the atmosphere of Sirius A reveal a history of nucleosynthesis. Sirius A has tightly constrained fundamental parameters due to its orbit with Sirius B, a measured interferometric diameter, and a precise parallax. Its slow rotation and apparent lack of atmospheric convection suggest one-dimensional model atmospheres should be a good approximation. Recent abundance analyses of Sirius A from Landstreet (2011) and Cowley et al. (2016) have employed local thermodynamic equilibrium (LTE) models in comparison to high-resolution spectra from the Hubble Space Telescope Imaging Spectrograph (HST/STIS), the Goddard High Resolution Spectrograph (GHRS), and the Very Large Telescope Ultraviolet Visible Echelle Spectrograph (VLT/UVES). In order to perform an abundance analysis for Sirius A that does not assume LTE, we have employed the PHOENIX model atmosphere code to compute 1-D non-LTE models and spectra. These models treat 194 species, 34976 levels and 600676 transitions in non-LTE for several ions of all elements from hydrogen to lead except Se, Br, Kr, Sb, Te, I, Xe, Pt, Au, Tc, and Pm to further constrain Sirius A's elemental abundances.

We have thus far compared our non-LTE abundance results with literature values for 30 elements and find six elements (N, Na, Cu, Mo, Ba, Os) have abundances which differ by more than 2 standard deviations (∼0.6 dex or more) from literature values. These results appear to differ from previous work for three reasons: (1) the latest oscillator strengths from Kurucz (2014) may differ significantly (2 to 10 times) from earlier values for specific lines and (2) non-LTE models show enhanced ionization of trace species relative to LTE which depletes these species and elevates the abundance needed to match the observed spectrum, and (3) non-LTE departure coefficient values for specific lines may different significantly from unity. We also find our model for Sirius A provides a good match to the observed spectral energy distribution in absolute units between 100 nm to 1 cm based on recent observations obtained by White et al. (2019) with ALMA, GBT, and the VLA.

108.03 — The SOFIA-FORCAST imaging survey toward Giant HII regions of the Galaxy

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The massive young stellar objects (MYSOs) crucially affect the ecology of their mother clouds due to the enormous feedback. Despite of the importance, we barely understand massive star forming mechanisms since they are rare, typically far at several kpc distance and deeply embedded in the densest parts of molecular clouds. Giant HII (GHII) regions in Milky Way are perfect laboratories to study the massive star formation since they are well known active star forming regions dominated by forming massive stars. In this poster, we present the current status of SOFIA-FORCAST 20 and 37 micron imaging survey toward the GHII regions of Milky Way. We also utilize the archival data from near-infrared to centimeter wavelength regimes in order to understand the physical properties and the relative formation histories of individual proto-stars as well as the porto-clusters. The analyses imply that the studied GHII regions possess MYSOs at their earliest evolutionary stages while entire areas show widely ranged life span of proto-clusters. These analyses toward all known GHII regions will provide us revolutionary point of views to massive star formation mechanisms.

108.04 — Angular momentum in bipolar outflows: dynamical evolutionary model

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We model molecular outflows produced by the time dependent interaction between a stellar wind and a rotating cloud envelope in gravitational collapse, studied by Ulrich. We consider spherical and anisotropic stellar winds. We assume that the bipolar outflow is a thin shocked shell, with axial symmetry around the cloud rotation axis and obtain the mass and momentum fluxes into the shell. We solve numerically a set of partial differential equations in space and time, and obtain the shape of the shell, the mass surface density, the velocity field, and the angular momentum of the material in the shell. We find that there is a critical value of the ratio between the wind and the accretion flow momentum rates β that allows the shell to expand. As expected, the elongation of the shells increase with the stellar wind anisotropy. In our models, the rotation velocity of the shell is the order to 0.1–0.2 km s^{-1}, a factor of 5–10 lower than the values measured in several sources. We compare our models with those of Wilkin and Stahler for early evolutionary times and find that our shells have comparable sizes at the pole, although we use different boundary conditions at the equator.

108.05 — XQCSAT: A High-Resolution Spectroscopic Study of Hot Gas in the Halo and Interstellar Medium

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We have completed a design feasibility study for a SmallSat carrying an array of microcalorimeter detectors optimized for the 100 – 1000 eV spectral range. It will have an energy resolution ~6 eV and a throughput of ~100 cm^2 deg^2, compared to 0.09 cm^2 deg^2 for XRISM/XARM/Hitomi and 50 cm^2 deg^2 for Athena. An instrument can be constructed that fits within the size/mass/cost envelope of a SmallSat and has a lifetime up to 60 days. This is short for a satellite, but even a 14-day science mission is the equivalent of 3,629 sounding rocket flights, which is the only alternative for obtaining these data until the Athena era begins in 2031+. We show some of the science questions that can be addressed by this mission.

109 — iPoster Session: Extrasolar Planets

109.01 — A Gaussian Process Regression Reveals No Evidence for Planets Orbiting Kapteyn's Star

Jinbiao Ji[1]; Hallie Fausey[1]; Anna Bortle[1]; Sarah E. Dodson-Robinson[1]; John Gizis[1]
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A significant issue with radial velocity (RV) planet searches is that they are often polluted by signals caused by activity on the star's surface. Stellar activity can mimic or mask changes in the radial velocities caused by orbiting planets, resulting in false positives. Here we test whether Gaussian process (GP) regression (e.g. Haywood et al. 2014) can distinguish star rotation from wobbles due to planets. We examine the RV and Hα data for Kapteyn's star, which has reported planets Kapteyn b and c with periods 48.6 and 121.5 days, respectively (Anglada-Escude et al. 2014). Based on the Hα observations, which trace magnetic activity in M dwarfs, Robertson et al. (2015) argued that Kapteyn b was an alias of the rotation. Here we use a quasiperiodic GP kernel to model rotation in the RV and Hα data jointly, requiring that their period and decorrelation timescale be the same. From this model, we construct residual RV datasets after subtracting off realizations of the GP rotation model. We find no evidence that Kapteyn's star hosts any planets, as there were no significant signals that remained in the residual data. We suggest that the periodic signals of the previously reported planets are both products of the star's rotation.

109.02 — A Search for Exoplanets in High Metallicity Open Clusters Using a Large-Scale Photometric Algorithm

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A star cluster is a group of stars in close proximity to each other that are gravitationally bound. Open clusters can contain about 100 to 1,000 stars. Stars in open clusters have the same origin, as they all formed from the same nebula. Open clusters are also composed of stars with the same age. These conditions make open clusters suitable for exoplanet formation, for new star harbor a lot of dust and gas in their surroundings. Gas and dust from young stars are two main factors in the process of new planet formation. Although all stars once existed in a cluster, no exoplanets have been discovered in open clusters. The purpose of this project is to observe whether exoplanets can form and remain in open clusters with high solar metallicity, to further the understanding about planetary formation and evolution. If we search for exoplanets in high-metallicity open clusters, then we should see a higher number of planets than we would expect in normal stars. For my research I have operated multiple 0.4m optical telescopes affiliated with the las cumbres global telescope network (LCO) and a 0.4m telescope located at the University of Dallas. With these telescopes I have taken observations of 3 open clusters; NGC 6791, NGC 2112, and NGC 6253. We hypothesize that the high metallicity of the stars in the open clusters may provide elements and materials needed to form exoplanets. My research has led to the discovery of 7 interesting transits that may be those of potential Hot-Jupiters. However, further observatins and data analysis needs to be conducted on these stars to confirm any current findings. 75 potential eclipsing binaries were also discovered in this research and we hypothesize that this is because of the relatively young age of the stars in these clusters, causing them to still be gravitationally bound to eachother.

109.03 — An Investigation of 3-D Climate Patterns on Hypothetical Earth-like Planets

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Studying extreme climate patterns on Earth-like planets as a function of atmospheric greenhouse gases, planetary obliquity, orbital eccentricity, solar irradiance variations and location within the host star's habitable zone is needed to determine whether such planets are habitable for life as we know it. Studying the behavior of climate on hypothetical Earth-like planets also provides insight into the future climate of our own planet. A database of climate models based on different orbital parameters, solar irradiance and atmospheric composition will provide a valuable resource to the astrobiology community in support of future detections of exoplanets with masses, sizes, and compositions similar to Earth. Due to its user-friendly interface to a research grade 3-D climate model code, the Educational Global Climate Model (EdGCM) was selected to perform a limited number of simulated models using the land configuration of Earth, but with varying amounts of greenhouse gases, orbital parameters, and axial tilts. It is found that the EdGCM is capable of simulating 3-D climate models for hypothetical Earth-like planets for a limited number of cases, with several important restrictions on the initial conditions.

110 — iPoster Session: Cosmology and Related Topics

110.01 — The Role of NED in Identifying EM Counterparts to GW events

David O. Cook[1]*; Joseph M. Mazzarella*[1]*; Rick Ebert*[1]*; Marion Schmitz*[1]*; Jeffery D. Jacobson*[1]*; Scott Terek*[1]*; Xiuqin Wu*[1]*; George Helou*[1]
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The detection of gravitational waves (GWs) has opened a new window into the Universe by enabling direct studies of mergers of massive, compact objects. Some of the largest impacts on our understanding of these events will come when combining the GW data with their electromagnetic (EM) counterparts. However, due to the large area (> 100 deg^2) localization of LIGO events, identifying their correct EM counterparts is no small feat and is akin to finding a needle in a haystack. This search is and will continue to be difficult task due to the large (>100 deg^2) localization of LIGO events. To overcome this challenge several teams used a galaxy-targeted approach to successfully locate the EM counterpart to the neutron star-neutron star merger event GW170817. In this talk I introduce a new service of the NASA/IPAC Extragalactic Database (NED) that will provide prioritized lists of galaxies located within future LIGO 90% probability contours to facilitate searches for EM counterparts, starting with the O3 run scheduled to begin in April 2019. I will give an overview of the service, as well as an analysis of the local Universe NED galaxy sub-sample and comparisons with other local galaxy lists.

110.02 — (withdrawn)

This abstract was withdrawn.

110.03 — Strong Gravitational Lenses and Where to Find Them: Which Method Should We Be Using?

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Strong gravitational lenses are cases where a distant background galaxy is located directly behind a massive foreground galaxy, whose gravity causes the light from the background galaxy to bend around the foreground galaxy. In addition to being visually stunning, these rare events are useful laboratories for furthering our understanding of gravity and to determine properties, such as the mass, of the lensing galaxies themselves. The trouble is finding enough of these strong gravitational lenses for further study. The immensity of the catalogs being collected by state-of-the-art telescopes requires equally innovative methods for interpreting that data. We are interested in three such techniques for identifying strong lenses: mixed spectroscopy, machine-learning, and citizen-science. Spectroscopy involves studying the objects' signatures across the electromagnetic spectrum and is a tried-and-true, reliable method. Machine-learning promises to find more and potentially different cases of lensing through teaching the computer to recognize features of lensing through visual templates. Citizen-science is a broad term for the inclusion of science-enthusiasts in the process of analyzing images on a scale too large to be undertaken by a small team of experts. For the first time, all three detection techniques have been used in the same regions of the sky, where the Kilo Degree Survey (KiDS) overlaps three regions of the Galaxy and Mass Assembly (GAMA) survey. We have all three catalogs of strong lenses in hand and plan to analyze the strengths and weaknesses of each method. We expect to uncover inherent biases and advantages to each method in finding a variety of lensing cases, which will serve as a directory for selecting the preferred methods to be used in new research toward these phenomena based upon the characteristics of the target galaxies. With astronomy moving into the era of large-scale imaging surveys, we will need to know which of the three techniques works best for detecting these rare astronomical events.

111 — iPoster Plus I: Solar Physics Division (SPD), The Corona

111.02 — Mapping low solar corona flow trends via time dependent AIA image processing

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The Atmospheric Imaging Assembly/Solar Dynamics Observatory (AIA/SDO) has captured high resolution, continuous ultraviolet images of the Sun since 2010. Applying the Time-Normalized-Optical-Flow (TNOF) image processing technique to AIA Extreme Ultraviolet (177–305 nm) data reveals fine-scale and faint plasma motion that are tracked through optical flow methods, giving 2-D flow maps. The motions are faint and impossible to analyze without advanced processing due to the dominance of the signal range by spatial gradients: these are removed by the TNOF process that operates solely in the time domain.

The ubiquitous, continuous flows appear to be oriented in the low corona [1,2]. The Lucas-Kanade optical flow algorithm [3] is currently limited to regions near disk center due to projection effects near the limb, and is also limited to the higher-signal channels of AIA. To refine the method, synthetic solar image data has been developed with a defined velocity field and serves as the testing platform to isolate systematic biases from true flows. Here, we present comparisons between the robustness of two optical flow algorithms: Lucas-Kanade, and Horn-Schuncke [4] and their ability to estimate the underlying velocity field. A line-integral convolution [5] is used to effectively visualize the consistency of flow paths. The refined system for mapping flow trends is then applied to a sample AIA dataset, with the aim of characterizing the faint moving disturbances that propagate, persist, and appear to be the standard solar condition in the "quiet sun". Additionally, the velocity field reveals large-scale flow behavior associated with (i) coronal rotation and (ii) a statistical relationship between velocity relative to the angle of the solar radial-observer vectors. We believe the flow fields are closely tied to the underlying coronal magnetic field.

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111.03 — Capturing CMEs in SUVI-ECI data

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The SUVI instrument on GOES-17 (now GOES-West) spent a month between August and September, 2018 conducting an extended coronal imaging campaign. Composite images constructed from interleaved image sets that scanned ±4 solar radii across the Sun every ∼6 minutes were processed to create a consistent dataset for analysis. An optical flow method (opflow3d) was applied to this set to estimate velocities of moving features. The results were then compared to CMEs detected by the CACTUS algorithm operating on co-temporal LASCO images. While the peak speeds reported by opflow3d were significantly lower than the CMEs found further out in the corona by CACTUS, the time intervals of enhanced motions correlate well between the two sets. Here we present the data and discuss the processing, analysis and future work. A new set of observations are scheduled to begin in mid-April. If they begin on time we may report on those results too.

111.04 — Long-lasting Conjugate Coronal Dimmings Produced by a Filament Eruption: Implications for Global Magnetic Connectivity

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Coronal dimmings, typically observed at extreme ultraviolet (EUV) wavelengths, are commonly associated with solar eruptions, such as coronal mass ejections (CMEs) and eruptive filaments. They offer critical clues to our understanding of the underlying mechanisms and consequences of solar eruptions. We present a study of an intriguing dimming event associated with a quiescent filament eruption on March 6, 2018 observed by SDO/AIA, STEREO/SECCHI, and IRIS. There were notably sigmoid-shaped, conjugate dimmings that appeared concurrently in multiple EUV channels, but evolved asymmetrically with time. One of the double dimmings lasted more than two days, which clearly sets it apart from the typical lifetime of several hours in previously reported dimmings. We investigated the temperature and density evolution of the dimming features, as well as the eruptive filament itself. We uncovered large-scale magnetic field connectivity between the conjugate dimmings and remote coronal holes where brightenings were observed around the time of the eruption. These remote brightenings are possible precursors of the eruption or manifestations of its associated global magnetic reconfiguration process. These results are significant because they allow us to use dimmings as tracers to probe the Sun's magnetic connectivity and the mechanisms responsible for the initiation of space-weather driving solar eruptions.

112 — iPoster Plus II: The Sun, Solar System & Public Policy

112.01 — What is the role of flare ribbon structure on CME speeds?

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Coronal mass ejections (CMEs) are the primary drivers of severe space weather disturbances, but remain poorly understood. Hence, efforts to characterize and predict their dynamics are ongoing. Many CMEs are associated with solar flares, and, in particular, flare ribbons, which are bright bands of strongly enhanced emission originating above magnetized areas of the photosphere. As a solar eruption progresses, these ribbons typically move across areas that contain fluxes of order 10^{21} Mx or more. The rate at which the ribbons sweep across photospheric flux is thought to correspond to the rate of coronal magnetic reconnection. Previous studies found significant correlations between CME speeds and the total amount of flux swept by flare ribbons. Here, we investigate relationships between CME speeds and spatial moments of their source-region photospheric magnetic fields and flare ribbons, including spatial moments of: (i) magnetic flux in the source region; (ii) signed and (iii) unsigned magnetic flux within ribbon areas; and (iv) binary maps ribbon areas. Our sample consists of $N = 75$ CMEs in the SOHO/LASCO CME catalog that were manually associated with flare ribbons identified in SDO/AIA data. Vector magnetograms obtained by SDO/HMI were used in our calculations of source-region magnetic properties. We confirm prior results that correlations between CME speeds and total magnetic fluxes swept by flare ribbons are statistically significant. We also find that spatial moments of ribbon magnetic fields are also significantly correlated with CME speeds.

112.02 — Navigating the Ownership of Extracted Parts of Celestial Bodies

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Celestial bodies remain free from claims of ownership by sovereign nations and their subjects. Yet, significant debate exists on whether ownership can be claimed over extracted parts of such celestial bodies. Although a mining company cannot claim ownership of the Moon or Mars, could it claim ownership of elements and minerals extracted therefrom? An analysis must begin with international space law. The current paradigm includes five (5) treaties. And, their relevant portions give rise to the very debate at issue. Consequently, guidance must be sought elsewhere. Perhaps not surprisingly, the tenets and established principles of maritime law exhibit instructive similarities.

Under the United States and English Common Law system, maritime law established rules of engagement beyond the borders of individual sovereign nations. In open waters over which no nation or person could claim ownership, maritime jurisprudence established principles of law that guided parties for centuries. Given the analogy to space and the absence of territorial boundaries, it serves as a model for space law.

In fact, beyond the ownership of elements and minerals extracted from celestial objects, these principles of law can address abandoned spacecraft, satellites, and other man-made objects (or fragments thereof) occupying various orbits around and beyond Earth. Indeed, the research on these historical principals (based on United States and the English Common Law System) give constructs to a proposed basis for international law governing ownership in space. That being said, any proposal will also need to accommodate extra-legal factors such as principals of scientific research, the policies and requirements guiding planetary protection, multidisciplinary ethics, and consideration of factors yet unknown.

The presentation will address a hint of existing celestial ownership space law and a distinction between three maritime principles. From the most applicable principle, proposed tenets will be revealed with an admission as to certain shortcomings and need for further exploration. It will conclude with an invitation for comment and discussion on the critical extra-legal factors.

112.03 — Local Weather Conditions and Sky Brightness

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Poor and inefficient outdoor lighting has a negative impact on the environment, and the resulting light pollution greatly hampers our ability to enjoy the beauty of the night sky and to do astronomy research. The 'light pollution research group' at Truman State University (Kirksville, Missouri) has set up *Unihedron sky quality meters* at various locations around Kirksville to quantify the sky brightness. In the past year, a weather station, a cloud-sensor, and an all-sky-camera have been set up at the Truman State Observatory to monitor the weather conditions and cloud coverage in the Kirksville area. We present results based on data obtained from these sensors. We correlate the sky brightness measured by the *Unihedron* light sensors with cloud coverage, humidity, and temperature. Pictures takes from the all-sky-camera are used to visually ascertain the changes in the sky brightness as a function of these weather parameters. Our results indicate that the sky brightness is greatly affected by even modest amounts of cloud coverage, whilst the temperature and humidity do not affect sky brightness significantly. We plan on repeating this exercise at urban locations (university campuses) and dark sky locations (state/national parks) in order to quantify the level of sky brightness and its correlation to local weather conditions. This work is part of our effort to quantify and mitigate the nuisance of light pollution in the Kirksville area. Apart from data collection and analysis, we have successfully lobbied to obtain close to $10,000 over the past two years to install 'dark sky reflectors' (light shields) on unfriendly outdoor light fixtures, and to replace the white (5000K) lights with friendlier yellow (3000K) lights. We call on amateur and professional astronomers to act now to save our night skies, and provide an outline for actions to bring about similar changes on other campuses and towns.

113 — Extrasolar Planets

113.01 — Lessons Learned and Fascinating Finds from a Manual Vetting of Conflicted KOIs

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Over the course of the Kepler mission, a total of 9,564 Kepler Objects of Interest (KOIs) were identified via eight KOI catalogs. Each catalog examined a different initial set of transiting planet search detections, and each catalog utilized a different vetting procedure to distinguish valid planet candidates from false positives — manual vetting in early catalogs, and fully automated vetting in later catalogs tailored for exoplanet occurrence rate studies. As a result, many KOIs were vetted multiple times, with over 1,400 KOIs having conflicting dispositions, being labeled "planet candidate" in at least one catalog and "false positive" in at least one other. An effort was undertaken by the Kepler False Positive Working Group (FPWG) to manually and individually review each of these conflicted KOIs, using the latest Kepler data, diagnostics, and follow-up observations available. In this talk, I will present the findings from this manual review, which include insights on potential pitfalls in automated vetting, a check on statistical planet validation, and possibly overlooked, scientifically unique planet candidates and variable stars.

113.02 — How Flares regulate Atmospheric Losses from the TRAPPIST-1 planets

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Stellar flares are considered an impediment to habitability, especially in the case of close-in exoplanets around M-dwarfs since these stars are highly active. In recent times, there has been a growing awareness that coronal mass ejections (CMEs) - sometimes termed as stellar storms or superstorms, depending on the flare energy - associated with stellar flares pose severe threats to planetary habitability. Interplanetary CMEs (or ICMEs), corresponding to fast-moving magnetic clouds, act to impact the planets with significantly high dynamic pressure. Semi-analytical models imply that planets around active stars ($\sim$1 flare/day) may experience escape rates that are 1-3 orders of magnitude higher than those arising from erosion by stellar winds alone. Understanding atmospheric escape is very important from the standpoint of habitability since atmospheric evolution influences the climate and the fluxes of ionizing radiation reaching the surface, among other factors. Here we carry out sophisticated 3D multi-species MHD simulations to assess how the atmospheric escape rates of the TRAPPIST-1 planets evolve during the passage of an ICME, where the ICME is initialized and modeled according to the flare observations.

113.03 — Atmospheric Responses to Radiative Forcing: Physics and Observability of Close-in and Highly Eccentric Planets

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The thermal emission of exoplanets contains valuable information about the structures of their atmospheres. However, the current quality of observations allows for only a limited understanding of the physics at play. With this in mind we focus on infrared observables of close-in and eccentric planets, whose atmospheric responses may be characterized to leading order by the cycles of stellar forcing from their orbits and rotation. We approach modeling using a range of physical complexities. Firstly, we demonstrate in a re-assessment of Spitzer orbital phase curves that their shapes in many cases are well fit by a simple thermal model, in comparison with models of considerably more complexity. A few Hot Jupiters show phase offsets counter to the expectation of super-rotating winds on a tidally-locked planet; we detail the efficacy, feasibility, and observable consequences of high planet obliquity in reproducing these offsets. Finally, we explore the broad effects of high eccentricity and rotation rate on potentially observable phase variations from ocean-rich worlds, using the capabilities of a fully 3-dimensional climate model.

113.04 — (withdrawn)

This abstract was withdrawn.

113.05 — A New Kepler Occurrence Rate Using DR25 Completeness and Reliabilty

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We present a new occurrence rate estimate based on the Kepler DR25 catalog for exoplanets with period between 50 and 400 days and radius between 0.75 and 2.5 Earth radii around GK dwarf stars. We make full use of the DR25 completeness and reliability products, introducing a new treatment of vetting completeness and reliability as realizations of binomial processes with variable rates. This approach is robust against the choice of sampling resolution and does not require restricting the sample to high-reliability planet candidates. We use the stellar properties of Berger et. al. 2018 and 2019 which includes Gaia-derived stellar radii. This is one of the first occurrence rate estimates to use the reliability data from DR25, which is a significant factor that impacts occurrence rate calculations. For exoplanets with period and size within 20% of that of Earth, we find lower occurrence rates than those previously published, partly due to the increased exoplanet radii revealed by Gaia data, and partly due to the impact of low reliability for small planets near one-year orbits.

113.06 — Planet Population Demographics for Radial Velocity and Direct Imaging Yield Calculations

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Planet yield calculations are crucial to the science operations and target selection strategy of space observatories. We are developing a series of numerical simulations to quantify how ground-based radial velocity surveys could boost the detection efficiency of forthcoming NASA direct imaging missions such as WFIRST, HabEx and LUVOIR. As a first step, we generate synthetic planet systems based on the observed occurrence rates from multiple planet detection methods. We implement a stability criterion for multi-planet systems based on mutual Hill radii separation. It is found that naive extrapolation of planet occurrence rates results in an unstable high occurrence rate at large semimajor axes. Imposed stability criteria therefore result in a marked suppression of low-mass planets at large semimajor axes compared to extrapolated rates. A consequence of tight dynamical packing, this result has a pronounced impact on planet yield calculations, particularly in the regions accessible to both RV and high-contrast imaging measurements. The dynamically self-consistent occurrence rates that we develop may be incorporated as input into joint RV and direct imaging planet yield calculations.

114 — Laboratory Astrophysics Division Meeting (LAD): Bridging Laboratory & Astrophysics: Molecules and Spitzer I

114.01 — LAD Career Prize: At the Interface: Laboratory and Radio Astronomical Spectroscopy of Exotic Interstellar Molecules

Lucy M. Ziurys[1]

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Observations of molecules in the interstellar medium (ISM) have shown that the chemistry in space is full of surprises, with the appearance of many unusual, "non-terrestrial" species. Using high resolution rotational spectroscopy in the laboratory, combined with millimeter-wave astronomy, we have pursued the identification of these exotic molecules in the ISM, in particular those containing metals (in the chemists's sense) or phosphorus. The laboratory studies have been conducted with millimeter/sub-mm/THz direct absorption spectrometers, as well as a pulsed, Fourier transform microwave/mm-wave instrument, all designed and built in the Ziurys group. Critical to the laboratory work has been the development of synthetic techniques to create the desired molecules, which are typically free radicals.

These lab studies have enabled us to identify new magnesium, aluminum, iron and even vanadium-bearing molecules, such an MgCN, AlNC, FeCN, AlOH, and, most recently, VO, typically found in circumstellar envelopes of evolved stars, along with phosphorus-containing species such as CCP. A key to success in this work has been the synergy between the lab studies and observations. Many of the detections were made at the telescopes of the Arizona Radio Observatory (ARO) and required sensitive, stable instrumentation, that we implemented. Also, the molecular identifications were often aided by observing "non-standard" sources. For example, our pioneering studies of the oxygen-rich envelope of supergiant VY CMa led to the first discoveries of circumstellar metal oxides and hydroxides. Our more recent observations have suggested that planetary nebulae may hold some interesting molecular secrets. Even more recently, we have teamed with solid-state spectroscopists in the investigation of "presolar" grains extracted from meteorites, and may have found to a facile route to large carbon molecules from SiC destruction.

114.02 — Unlocking the star-formation freezer; showing how laboratory studies are vital in understanding interstellar ices — from SPITZER and AKARI to the ALMA / JWST era.

Helen Jane Fraser[1]

[1] *Astronomy, The Open University (Milton Keynes, United Kingdom)*

The Spitzer space telescope revolutionised our view of the cold, solid-state local universe, by revealing a rich mid-IR (M to N band) spectroscopy between 5 and 20 microns, associated with a wealth of icy material in star-forming regions. Consequently an "average" interstellar ice "mix" has been proposed. Subsequently, AKARI observations have enabled us to map the distributions of simple molecular ices, such as CO, CO_2, H_2O and CH_3OH across star-forming regions at unprescedented resolution — but these results strongly indicate small scale solid-state chemical varability — at least of scales down to ~1000 AU. And now ALMA is revealing a whole molecular universe which (in the gas-phase at least) varies on scales of only a few AU, and strongly hints that both chemical complexity and grain growth are fundamentally dependent on ice contituents and properties.

To fully understand what we are observing and the role ices play in evolving the by-products of star-formation is a challenge that can *only* be resolved in the laboratory. Three fundamental questions remain unanswered: (a) what is the structure of interstellar (water) ice (and is it porous)? (b) to what extend does (water) ice aid the earliest stages of planet formation through collisions? (c) how does chemical complexity emerge (in the solid state)? In this invited talk I'll very breifly illustrate one example where innvoative laboratory experiments are enable us to start understanding these issues, and relate our findings back to observational data. First I'll show how we can probe the (water) ice porosity using neutron scattering techniques, to concurrently elucidate the molecular structure and mesoscale porosity of the material — and even watch the pores collapse. Second I'll show how we can use these same neutron techniques to explain "why ices stick" and look at what happens if we make more "protoplanetary disk" like ices in the laboratory and then collide them — can we build planets at all? Finally I'll illustrate our newest laboratory development-THz DES (desoprtion emission spectroscopy) and its potntial to aid our understanding of COM formation and evolution in star-forming regions.

114.03 — Supersonic Gas Jets as an Interaction Medium for Laboratory Photoionized Plasmas

Kyle James Swanson[1]*; Vladimir Ivanov*[1]*; Roberto Mancini*[1]*; Daniel C. Mayes*[1]*; Nicholas Wong*[1]

[1] *Physics, University of Nevada Reno (Reno, Nevada, United States)*

Photoionized plasmas are important for a variety of astrophysical environments such as x-ray binary systems, active galactic nuclei, and accretion powered objects. Investigating photoionized plasma from afar does not allow for many options when it comes to collecting data, nor does it allow for in depth systematic studies of changing plasma conditions. Studying laboratory photoionized plasmas afford greater control over the parameter space. Typically, laboratory photoionized plasmas require large scale facilities that are capable of producing a high intensity broadband x-ray flux. The use of supersonic gas jets as an interaction medium allows university scale pulsed power generators to perform laboratory photoionized plasma research. Supersonic gas jets can be placed much closer to an x-ray source and they do not require any medium for containment or tamping, thus avoiding x-ray flux attenuation. The experiments were carried out using the Zebra accelerator, a 1 MA pulsed power generator, at the University of Nevada Reno. Zebra is capable of producing 12-16kJ of x-ray energy, with photons under 1keV in energy, from the implosion of z-pinch wire-arrays. Neon, argon, and nitrogen gas has been investigated utilizing a variety of laser and x-ray diagnostics. Mach-Zehnder interferometry, at 266nm, is used to characterize the neutral gas jet before the Zebra shot. Dual-color air-wedge interferometry, at 532nm and 266nm, probe the electron density of the photoionized gas jet. Multi-color shadowgraphy, at 1064, 532, and 266nm, is used for further characterization of the plasma. A cylindrically bent KAP crystal spectrometer measures the x-ray absorption spectrum. Interferometry and x-ray absorption spectroscopy show electron areal densities of 1-3.5x10^{18} cm^{-2}. Interferometry measures electron densities in the range of 1-4x10^{19} cm^{-3}. This work was sponsored in part by the DOE NNSA HEDLP Grant DE-NA0003875, DOE Office of Science Grant DE-SC0014451, and the Z Fundamental Science Program.

115 — Cosmological Probes of Dark Matter I

115.01 — Introductory comments

Yacine Ali-Haimoud[1]
[1] *New York University (New York City, New York, United States)*

I will make brief intrductory remarks for this special session on cosmological probes of dark matter.

115.02 — Dark matter interactions: CMB spectral distortions and Neff.

Yvonne Wong[1]
[1] *The University of New South Wales (Sydney, New South Wales, Australia)*

It is well known that elastic scattering between dark matter and a radiation component can lead to interesting phenomenologies on small-length scales, some of which can be exploited to alleviate, e.g., the so-called small-scale crisis of dark matter. In this talk I discuss some other phenomenlogies of this scenario. In particular, I'll explain how such an interation can also lead to signatures in the CMB energy spectrum in the form of spectral distortions, and how elastic scattering can lead to a small change in the so-called effective of number of neutrinos parameter.

115.03 — Studying Dark Matter Interactions with the CMB

Kimberly K. Boddy[1]
[1] *Johns Hopkins University (Baltimore, Maryland, United States)*

There is a substantial effort in the physics community to search for dark matter interactions with the Standard Model of particle physics. The cosmic microwave background anisotropies are sensitive to energy injection from dark matter annihilations and to energy and momentum transfer due to dark matter scattering with baryons. These effects enable a broad search for dark matter interactions using cosmological observations in a parameter space that is complementary to that of indirect and direct detection experiments. In this talk, I will describe the effects of annihilation and scattering in cosmology and show constraints using Planck 2015 data. I will also discuss the implications of dark matter interactions during the era of Cosmic Dawn.

115.04 — Searching for Dark Matter at Cosmic Dawn

Julian B. Munoz[1]*; Yacine Ali-Haimoud*[2]*; Abraham Loeb*[1]*; Cora Dvorkin*[1]*; Ely Kovetz*[3]
[1] *Physics, Harvard University (Cambridge, Massachusetts, United States)*
[2] *NYU (New York, New York, United States)*
[3] *Ben Gurion (Beersheba, Israel)*

The nature of the dark matter is still a mystery, although current and upcoming 21-cm measurements during the cosmic dawn can provide a new arena on the search for the cosmological dark matter. This era saw the formation of the first stars, which coupled the spin temperature of hydrogen to its kinetic temperature — producing 21-cm absorption in the CMB. The strength of this absorption acts as a thermostat, showing us if the baryons have been cooled down or heated up by different processes. I will show what the 21-cm line can teach us about dark matter, focusing on the case of "millicharged" dark-matter, which can explain the anomalous 21-cm depth observed by the EDGES collaboration.

115.05 — Soft Spectral Distortions from Dark Photons

Joshua Ruderman[1]
[1] *Physics, New York University (New York, New York, United States)*

The Rayleigh-Jeans tail of the CMB is poorly constrained at low energies, and therefore could be highly distorted from a blackbody consistent with current measurements. I will describe how dark radiation, composed of dark photons, can inject soft photons from resonant oscillations during the dark ages. A small fraction of the Universe's energy in dark photons can produce large distortions in the Rayleigh-Jeans tail. Measurements of cosmological 21cm absorption test the CMB spectrum at low energies, because injected 21cm photons produce deeper absorption than the standard cosmology, as tentatively observed by the EDGES experiment. A smoking gun of dark photon oscillations is the presence of sharp edges, as a function of redshift, in the 21cm signal.

116 — Instrumentation: Ground Based, Computation, etc.

116.01 — XL-Calibur: Plans for a Next-Generation Hard X-ray Polarimeter

Quincy Abarr[1]
[1] *Physics, Washington University in St. Louis (St. Louis, Missouri, United States)*

X-Calibur is a hard X-ray scattering polarimeter which flew for a short stratospheric balloon flight from McMurdo, Antarctica during the 2018-2019 austral summer. This flight resulted in preliminary limits on the polarization properties of GX 301-2, an accreting pulsar.

Following up on this promising first result, here we will present plans for a successor mission: XL-Calibur. This is based on the X-Calibur design, but is expected to have sensitivity roughly six times greater. Upgrades include: thinner CZT detectors in the polarimeter to reduce background; using the spare mirror from the Hitomi satellite, which increases the effective area in the key energy range of 20-40 keV by four; and modified shielding around the polarimeter to further reduce background.

Using this upgraded instrument in two northern and one southern hemisphere balloon flights (in 2021, 2022, and 2024, respectively), we will be able to observe both neutron stars, like GX 301-2, and black holes, like Cyg X-1. Polarimetric observations will provide systematically new information on the geometry of these sources and their surroundings.

116.02 — Bayesian Methods in Spectral Energy Distribution Fitting of Galaxies

Andrew Lawler[1,2]; *Viviana Acquaviva*[2]
[1] *Baylor University (Waco, Texas, United States)*
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Bayesian statistical methods have been used in recent years to aid in SED fitting. Typically, Markov Chain Monte Carlo sampling techniques have been used in a Bayesian framework to arrive at posterior distributions of parameters of interest given the available data. We perform Bayesian model comparison of nested SED models by estimating the Bayesian evidence. Our analysis is one of the first to make systematic use of the Bayesian model comparison method to answer questions about galaxies' star formation histories and dust attenuation laws. Nested sampling is superior to MCMC in this case becase it is suitable for handling multimodality of posteriors and non-normal likelihoods, parameter degeneracies, and calculating the Bayesian evidence to an accurate level for model comparison.

We use multi-wavelength photometric data from the 3D-HST catalogs to model the spectral energy distribution of galaxies at z=1, z=2, and z=3 in 23 bands. Kernel density estimation of both the observational measurement errors and parameter space is used in a tau model to generate realistic galaxy spectra. We then fit the model parameters to this simulated data using nested sampling to verify the viability of both the model and the sampling algorithm.

Another important byproduct of our analysis is the direct testing of an analytic approximation of the Bayes factor, known as Savage-Dickey Density Ratio (SDDR), which is valid in the regime in which nested models are compared. We test this assumption directly by comparing the Bayes factors obtained through nested sampling and those obtained through the SDDR.

We then assess the effects of software-specific nested sampling implementations in SED fitting, such as consistency of point estimates, how the number of the number of live points used in the nested sampling run affect the efficiency and bias, and the effect of dimensionality. Nested sampling runs can be divided into independent "threads", which enables us to use standard resampling techniques such as bootstrapping to the set of threads to approximate the entire error distribution without making assumptions about its form.

116.03 — Multi-component Decomposition of Astronomical Spectra by Compressed Sensing

Mark Cheung[1,2]; *Bart De Pontieu*[1,8]; *Juan Martinez-Sykora*[1]; *Paola Testa*[3]; *Amy R. Winebarger*[4]; *Adrian N. Daw*[5]; *Viggo Hansteen*[6,8]; *Patrick Antolin*[7]; *Theodore D. Tarbell*[1]; *Jean-Pierre Wuelser*[1]; *Peter R. Young*[5]
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[7] University of St Andrews (St Andrews, United Kingdom)
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The signal measured by an astronomical spectrometer may be due to radiation from a multi-component mixture of plasmas with a range of physical properties (e.g. temperature, Doppler velocity). Confusion between multiple components may be exacerbated if the spectrometer sensor is illuminated by overlapping spectra dispersed from different slits, with each slit being exposed to radiation from a different portion of an extended astrophysical object. We use a compressed sensing method to robustly retrieve the different components. This method can be adopted for a variety of spectrometer configurations, including single-slit, multi-slit (e.g., the proposed MUlti-slit Solar Explorer mission; MUSE) and slot spectrometers (which produce overlappograms).

116.04 — An Efficient, High-Fidelity Survey Simulator for Pan-STARRS-1

Matthew J. Holman[1]; Matthew J. Payne[1]
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Survey simulators are an essential tool for determining the efficiency and detection biases of searches for solar system bodies, as well as for developing and testing the algorithms. Without such tools, it is difficult to determine the intrinsic populations underlying the subset of objects observed. Such simulators have been developed for CFEPS/OSSOS, NEOWISE, and other surveys, leading to detailed results on the small body populations throughout the solar system.

For those surveys, the detection of moving objects results from the analysis of a small number of exposures taken over a relatively short period of time. Therefore, the survey simulators focus on the number of objects that appear in each field of view within the survey, as well as the magnitudes of those objects.

Giga-Pixel Camera-1 (GPC1) on the Pan-STARRS-1 telescope has a large, 3 degree diameter field of view, with a focal plane tiled with 60 detectors, each of which contains 64 independently-addressable cells. There are physical gaps between the detectors and insensitive regions between the cells. In addition, many of the cells are either dead or noisy.

Furthermore, much of the data from Pan-STARRS-1 was collected in surveys designed to meet a number of science objectives without being optimized for any one of them. As a result, the discovery of moving objects in much of the data requires exposures collected over weeks, months, and years. Properly identifying and correcting the biases introduced by the sensitivity irregularities of GPC1 used in such survey modes requires a more detailed survey simulator.

We present a survey simulator for Pan-STARRS-1 that captures the relevant details of the detection of moving objects, and we report the results of applying this novel tool to our ongoing outer solar system searches.

117 — Solar Physics Division Meeting (SPD), Corona 1

117.01 — Hi-C2.1 Observations of Solar Jetlets at Sites of Flux Cancelation

Navdeep Panesar[1]; Alphonse C. Sterling[1]; Ronald L. Moore[1]
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Solar jets of all sizes are magnetically channeled narrow eruptive events; the larger ones are often observed in the solar corona in EUV and coronal X-ray images. Recent observations show that the buildup and triggering of the minifilament eruptions that drive coronal jets result from magnetic flux cancelation under the minifilament, at the neutral line between merging majority-polarity and minority-polarity magnetic flux patches. Here we investigate the magnetic setting of six on-disk small-scale jet-like/spicule-like eruptions (also known as *jetlets*) by using high resolution 172A images from the High-resolution Coronal Imager (Hi-C2.1) and EUV images from Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) and line-of-sight magnetograms from SDO/Helioseismic and Magnetic Imager (HMI). From magnetograms co-aligned with the Hi-C and AIA images, we find that (i) these jetlets are rooted at edges of magnetic network lanes (ii) some jetlets stem from sites of flux cancelation between merging majority-polarity and minority-polarity flux patches (iii) some jetlets show faint brightenings at their bases reminiscent of the base brightenings in coronal jets. Based on the 6 Hi-C jetlets that we have examined in detail and our previous observations of ~30 coronal jets in quiet regions and coronal holes, we infer that flux cancelation is the essential process in the

buildup and triggering of jetlets. Our observations suggest that network jetlets result from small-scale eruptions that are analogs of both larger-scale coronal jet minifilament eruptions and the still-larger-scale eruptions that make major CMEs. This work was supported by the NASA/MSFC NPP program and the NASA HGI Program.

117.02 — Fine-scale explosive energy release at sites of magnetic flux cancellation in the core of the solar active region observed by HiC2.1, IRIS and SDO

Sanjiv K. Tiwari[1]; Navdeep Panesar[2]; Ronald L. Moore[2]; Bart De Pontieu[3]; Paola Testa[4]; Amy R. Winebarger[2]
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The second sounding-rocket flight of the High-Resolution Coronal Imager (HiC2.1) provided unprecedentedly-high spatial and temporal resolution (150 km, 4.5 s) coronal EUV images of Fe IX/X emission at 172 Å, of a solar active region (AR NOAA 12712) near solar disk center. Three morphologically-different types (I: dot-like, II: loop-like, & III: surge/jet-like) of fine-scale sudden brightening events (tiny microflares) are seen within and at the ends of an arch filament system in the core of the AR. We complement the 5-minute-duration HiC2.1 data with SDO/HMI magnetograms, SDO/AIA EUV and UV images, and IRIS UV spectra and slit-jaw images to examine, at the sites of these events, brightenings and flows in the transition region and corona and evolution of magnetic flux in the photosphere. Most, if not all, of the events are seated at sites of opposite-polarity magnetic flux convergence (sometimes driven by adjacent flux emergence), implying flux cancellation at the polarity inversion line. In the IRIS spectra and images, we find confirming evidence of field-aligned outflow from brightenings at the ends of loops of the arch filament system. These outflows from both ends of the arch filament system are seen as bi-directional flows in the arch filament system, suggesting that the well-known counter-streaming flows in large classical filaments could be driven in the same way as in this arch filament system: by fine-scale jet-like explosions from fine-scale sites of mixed-polarity field in the feet of the sheared field that threads the filament. Plausibly, the flux cancellation at these sites prepares and triggers a fine scale core-magnetic-field structure (a small sheared/twisted core field or flux rope along and above the cancellation line) to explode. In types I & II the explosion is confined, while in type III the explosion is ejective and drives jet-like outflow in the manner of larger jets in coronal holes, quiet regions, and active regions.

117.03 — The life of coronal bright points

Karin Muglach[1]; Andrew Leisner[2]
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Coronal bright points are small-scale magnetic regions found all over the solar disk. They are visible in coronal emission lines which sample plasma at around 1-2 MK. In this study we follow the complete lifetime of several coronal bright points, from the time they appear in the SDO/AIA coronal filtergrams to the time they fade again into the quiet solar background emission. In addition to the hot coronal emission, lower temperature chromospheric filtergrams (e.g. AIA 304 Å) sometimes show the formation of dark absorption structures similar to filaments. From SDO/HMI we can get the accompanying evolution of the photospheric magnetic flux density and also calculate the plane-of-sky plasma flow field using local correlation tracking. Most of the coronal bright points show some jet activity during their lifetime and these data allow to us to study both the energy buildup of the coronal bright point and the initiation of the jets.

117.04 — Polarimetric observations of the SiX and Fe XIII infrared coronal emission lines using the SOLARC telescope

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The forbidden Si X emission line at 14301 Å has been identified as a potentially valuable polarized diagnostic for solar coronal magnetic fields; however, the only polarized Si X measurements achieved to date have been during eclipses and at comparatively low spatial and spectral resolution. Here we report spectropolarimetric observations of both the Si X 14301 Å and more well-established FeXIII 10747 Å coronal lines acquired with the 0.45 m aperture SOLARC coronagraph atop Haleakala. Results for both lines, which represent averages over different active and non-active regions of the corona, indicate a relatively flat radial variation for the line widths and line centers and a factor of ~2-3 decrease in polarized brightness between 1.05 and 1.45 $R_\odot$. Averaging over all the measurements the mean and standard deviations of line properties for Si X 14301 Å and Fe XIII 10747 Å are respectively: FWHM of 3.0±0.4 Å and 1.6±0.1, line-integrated polarized brightness of 0.07±0.03 and 0.3±0.3 erg s^{-2} cm^{-2} sr^{-1} where the uncertainty quoted reflects a large sample variance, and line center wavelengths 14300.7±0.2 Å and 10746.3±0.1 Å. The polarized brightness for both lines may be underestimated by up to a factor of 5 due to limitations in the photometric calibration. When accounting for this uncertainty we find consistency between our observations and previous measurements of the two lines as well as theoretical calculations and affirm the potential of the Si X line as a polarized diagnostic of the solar corona.

117.05 — Measuring and modeling the rate of separator reconnection between an emerging and existing active region

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Magnetic reconnection must occur when new flux emerges into the corona and becomes incorporated into the existing coronal field. A new active region (AR) emerging in the vicinity of an existing AR provides a convenient laboratory in which reconnection of this kind can be quantified. We perform such a measurement using high time-cadence 171 Å data from SDO/AIA of active region NOAA AR11149 which emerged in the vicinity of AR11147 beginning on 20 January 2011. We make a spatial/temporal stack plot of the region between the ARs by extracting the pixels along a virtual slit. A persistent, bright streak in such a plot indicates a bright coronal loop connecting the newly emerging flux to the existing AR. This loop must have been formed through a process of coronal reconnection across the separator separating the four topologically distinct flux systems. We assume further that energy released during that reconnection is responsible for its brightening. We catalog 205 loops observed in the a 48-hour time period beginning with the emergence of AR 11149. The rate at which new magnetic flux appears is used to calculate the rate of separator reconnection. We can further fit these cataloged field lines using a linear force-free field (LFFF) extrapolation, solving for an individual loop's field strength and twist. Ultimately, we find the rate of newly-brightened flux overestimates the flux which could be undergoing reconnection. This excess can be explained by our finding that the interconnecting region is not at its lowest energy (constant-α) state; the LFFF modeling shows a variation in values of α. This overestimate might be the result of the region's unusually slow emergence, providing time for internal Taylor-relaxation reconnection of the interconnecting flux following its initial formation by reconnection. We support this hypothesis by computing the rates of brightening within the plane of the virtual slit. This work was supported by NASA's HGI program.

117.06 — Constraints from Hinode/EIS on the Expansion of Active Region Loops Along the Line of Sight

Therese A. Kucera[1]; Peter R. Young[1]; James A. Klimchuk[1]; Craig DeForest[2]

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We explore the constraints that can be placed on the dimensions of coronal loops out of the plane of the sky by utilizing spectroscopic observations from the Hinode/EUV Imaging Spectrometer (EIS). The usual assumption is that loop cross sections are circular. Changes in intensity not constant with the measured width are assumed to be the result of changing density and/or filling factor. Here we instead focus on the possibility that the loop dimensions may be changing along the line of sight while the filling factor remains constant. We apply these ideas to two cool (5.5<logT<6.2) loops observed by EIS with supporting observations from Solar Dynamics Observatory's Atmospheric Imaging Assembly (SDO/AIA) and the Solar TErrestrial RElations Observatory-A's Extreme Ultraviolet Imager (STEREO-A/EUVI). Our results are generally consistent with non-expanding loops, but allow for line-of-sight expansion factors up to 3-4. The uncertainties are sizable and are driven by count rate statistics, radiometric calibration of EIS, and the selection of the loop backgrounds.

118 — Solar Physics Division Meeting (SPD), Data & Computation

118.01 — Fractal Dimensions of Solar and Geomagnetic Indices

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Correlations between solar and geomagnetic indices are often used in space weather research. How sensitive are these correlations to pre-whitening of the data and auto-correlation within the data sets? Statistical and timeseries analyses of the sunspot number are often used to predict solar activity. These methods have not been completely successful as the solar dynamo changes over time and one cycle's sunspots are not a faithful predictor of the next cycle's activity. Can more accurate predictions be produced by partitioning the data into periods when it obeys certain statistical properties? The Hurst exponent and the related fractal dimension are two such ways to partition the data. We can use these measures of complexity to compare the sunspot number with other solar and geomagnetic indices. We use five algorithms to calculate the Hurst exponent or fractal dimension and examine what happens when the mean and a linear trend trends are removed. We find that some algorithms are robust and return similar or identical values for the original, mean-removed, and linear-trend-subtracted data. The behavior of the Fourier transform at low frequencies is the most sensitive to the type of pre-whitening applied to the data. The rescaled-range algorithm is robust but needs to be corrected for autocorrelation in the data.

118.02 — Advancing the Advective Flux Transport Model

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The Advective Flux Transport (AFT) model has proven to be a reliable surface flux transport model for describing the evolution of the global magnetic field, accurately reproducing the evolution of the polar field. AFT has also been shown to accurately (within a factor of 2) reproduce the evolution of the total unsigned flux of simple active regions over the course of their lifetimes. Here we will discuss the work being done to validate and advance the AFT model. We will discuss the ability of AFT to reproduce other active region properties, such as tilt angles, polarity separation, area expansion and magnetic elements size distribution, for simple and more complex active regions. Currently, AFT uses data assimilation to incorporate the magnetic field from magnetograms from the Earth's vantage point. We will also discuss the work that is being done to develop an automated process for adding in far-side active regions observed by STEREO in 304 Å.

118.03 — Mapping the Sun's Far-Side Magnetic Flux through a Machine-Learning Code Trained by Use of the Sun's Near-Side Observations

Ruizhu Chen[1]*; Junwei Zhao*[1]
[1] *Stanford University (Stanford, California, United States)*

The Sun's far-side magnetic field is crucial to space weather forecasting and solar wind modeling, but it cannot be directly observed. For about four years, the extreme ultraviolet (EUV) 304Å flux of the far side was observed by the STEREO/EUVI, providing a chance for us to map the far-side magnetic flux using a machine-learning method. We take about 6000 near-side SDO/HMI magnetic-field maps and SDO/AIA 304Å flux images, observed simultaneously and covering a period of about 8 years, and train a neural-network that is able to convert the EUV flux images into magnetic-flux maps. The trained network is then applied on a test set of SDO/AIA data, and the results are then compared with the SDO/HMI magnetic-field observations. Satisfactory agreements are found between the observations and the computer-generated maps. The trained machine-learning code is then applied on the STEREO far-side 304Å observations to generate the far-side magnetic flux maps. These data are useful to assess the validity of the far-side magnetic field produced by flux-transport models, and to examine the solar wind models with and without including the far-side magnetic field.

118.04 — New Space Weather Climate Record of the Solar Spectral Irradiance Variability over Solar Cycles 23 and 24

Thomas N. Woods[1]*; Francis Eparvier*[1]
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The solar irradiance is the primary natural energy input into Earth's atmosphere and climate system. Understanding the long-term variations of the solar spectral irradiance (SSI) over time scales of the 11-year solar activity cycle and longer is critical for most Sun-climate research topics. Of particular interest for the space weather community is the long-term variations of the solar extreme ultraviolet (EUV: 100-1250 Å) and soft X-ray (SXR: 10-100 Å) because those energetic photons create Earth's ionosphere and heat Earth's thermosphere. Consequently, the solar EUV and SXR variability is important for several space weather studies, such as understanding changes in the thermospheric density that affect satellite drag (and thus satellite life times).

There are on-going daily satellite measurements of the EUV and SXR SSI since 2002. These are being combined to create a new space weather climate record for the SSI in the 5 to 1900 Å range to understand the long-term variability over Solar Cycles 23 and 24. The primary SSI observations are from the Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE) and Thermosphere, Ionosphere, Mesosphere, Energetic, Dynamics (TIMED) Solar EUV Experiment (SEE). A limiting factor for the accuracy in making a composite SSI record is the uncertainty in the various instrument degradation corrections. A new analysis technique for trending SSI time series is helping to identify some uncorrected instrumental trends, which, once applied to the SSI trends, can improve the long-term SSI accuracy. The SDO and TIMED time series, this new technique for trending, and the new composite SSI record will be presented.

118.05 — Reliably Inferring the Sun's Far-Side Magnetic Flux for Operations Using Time-Distance Helioseismic Imaging - Updates

Shea A. Hess Webber[1]; Junwei Zhao[1]; Ruizhu Chen[1]; Jon Todd Hoeksema[1]; Yang Liu[1]; Monica Bobra[1]; Marc L. DeRosa[2]

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Solar wind models are highly dependent on global magnetic fields at the solar surface as their inner boundary condition, and the lack of global field data is a significant problem plaguing solar wind modeling. Currently, only near-side magnetic field observations exist and far-side approximations are incapable of predicting growth of existing active regions or new magnetic flux emergence. We therefore plan to develop a method that calibrates far-side helioseismic images, calculated using near-side Doppler observations, to far-side magnetic flux maps to fill this data gap. The calibration will employ machine-learning methods that use EUV 304 Å data as a bridge: a relation will be sought 1) between the near-side AIA 304 Å data and HMI magnetic field data, and 2) between STEREO 304 Å data and far-side helioseismic images obtained from a newly developed time-distance helioseismic far-side imaging method. As an update, progress has been made in establishing the relation between the near-side 304 Å data and magnetic flux data, and some previously-unknown systematics were identified and corrected in the helioseismic far-side images. These systematic-effect-corrected far-side images will then be used to establish a relation with the far-side EUV data.

118.06 — HelioML: An interactive online book at the crossroads of heliophysics and machine learning containing the code behind published papers

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The subcomponents of artificial intelligence, machine and deep learning, have already been used in peer-reviewed papers in heliophysics. In order to understand these papers as readers and as peer reviewers, we need to have at least a passing familiarity with how these new techniques work. It's not magic but it's not trivial either. We set out to make an online book with code examples and lots of explanatory text to show how machine/deep learning have actually been employed in heliophysics research to date. Everything in the book is written in open source python. There's an "Interact" button at the top of each chapter that, with one click, will spin up a computer in the cloud for you and 10 seconds later you can edit and execute the code in the chapter. Or you can download the code and play with it locally. Each chapter is written by a contributor and is associated with a published paper. We're also looking for more. We presently cover a variety of heliophysics and machine learning topics (see full list here [1]): Classification, model selection, image processing, regression, image transformation; space weather prediction from magnetograms, image resolution enhancement, and simulating data from a lost instrument. Check the book out here [2] and the source code is here [3].

[1] `https://helioml.github.io/HelioML/01/2/in_this_book` [2] `http://helioml.org` [3] `https://github.com/HelioML/HelioML`

119 — Helen B. Warner Prize Lecture: Hunting for Dark Matter in the Early Universe, Yacine Ali-Haïmoud (New York University)

119.01 — Hunting for dark matter in the early Universe

Yacine Ali-Haimoud[1]
[1] *New York University (New York, New York, United States)*

It is now well established that a large part of the matter in the Universe is some substance which appears to be oblivious to any force but gravity. The nature of this "dark matter" remains a mystery. Could it be a new particle, as light as an electron, or might it be made of black holes as massive as many Suns? In this talk, I will first describe how one can hope to tease out some of the properties of dark matter from the Cosmic Microwave Background (CMB), the relic radiation from the very early Universe. I will review the basic physics underlying the CMB, in particular why it has a nearly perfect blackbody spectrum, and what the tiny changes of temperature across the sky tell us about the history and contents of the Universe. I will then illustrate how precise measurements of the CMB properties may inform us about the nature of dark matter. Last but not least, I will explain how gravitational waves, recently directly detected by LIGO, may provide an entirely new window into the mystery of dark matter.

121 — Laboratory Astrophysics Division Meeting (LAD): Bridging Laboratory and Astrophysics: Exoplanets I

121.01 — Exploring Exoplanet Clouds at Home and Abroad

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From the shrouds of Venus and Titan to Jupiter's great red spot and the veil of Pluto, clouds and hazes are a ubiquitous feature of the planetary atmospheres in our solar system. As we extend our gaze beyond to learn about our nearest stellar neighbors we have discovered a breath taking array of extrasolar planets (or exoplanets). Understanding the atmospheres and underlying surfaces of these planets is of tremendous interest, but the presence of clouds and hazes pose great challenges for direct observation of these features.

Despite the challenge I hope to convince you that *we don't need to see through the clouds* to learn about the underlying atmosphere, but rather *we can use the physical properties of exoplanet cloud particles to our advantage.* One way to do this is through careful, laboratory-based measurements of scattering and the polarization of scattered light by exoplanet cloud analogs.

The physical properties of cloud particles (size, shape, composition) and how they interact with light are explicitly tied to their trajectory through, or history within, an atmosphere. Thus, the thermodynamic conditions, atmospheric chemistry, dynamical processes, and nucleation mechanisms to which the particle was exposed all play a role in determining its physical properties and the way it scatters and polarizes light. We will discuss how laboratory-based measurements of scattering and polarization are currently being conducted, how this data can start to pin down signals in light scattered by exoplanet clouds, and how it might be used to identify cloud properties from planetary phase curves in the future. We will also discuss what this data can teach us about portions of an atmosphere we cannot observe, such as below an optically thick cloud deck, and improve our understanding of radiative balance in these exotic systems.

121.02 — Laboratory Exploration of Photochemistry and Aerosol Formation in Exoplanet Atmospheres

Nikole K. Lewis[1]
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The importance of photochemistry and aerosols (clouds and hazes) in the atmospheres of solar system objects has long been recognized. As observations aimed at characterizing the atmospheres of exoplanets have increased in fidelity, it has become clear that aerosols and photochemistry also play a critical role in planets beyond our solar system. The phase space of stellar irradiation, temperature, chemical composition, and planetary size spanned by exoplanets is much greater than that spanned by planets in the solar system, which limits our ability to leverage solar system analogs to understand key atmospheric processes. Recently, efforts have begun to explore photochemistry and aerosol formation in exoplanet atmospheres through laboratory simulations of the relevant environments. In this talk, I will provide an overview of results from laboratory explorations of exoplanet atmospheres and discuss future needs. With a new wave of exoplanet observations coming in the next decade from ground and space-based facilities, such as JWST, laboratory work focused on exoplanet photochemistry and aerosol formation will prove increasingly critical for understanding these distant worlds.

121.03 — The new NASA Ames Infrared Optical Constant Facility. Determinations for Titan Aerosol-, and Exoplanet and Brown Dwarf Cloud Particle Analogs

Ella Sciamma-O'Brien[1]; Ted L. Roush[1]; David F. Dubois[1,2]; Caroline Morley[3]; Mark S. Marley[1]; Farid Salama[1]

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Here we present a new optical constant facility developed at NASA Ames that will allow the determination of optical constants in the infrared of various materials, analogs of hazes and cloud particles in (exo)planet atmospheres and brown dwarfs. Our facility is composed of a Fourier Transform Infrared (FTIR) spectrometer continuously covering the Near-IR, mid-IR and Far-IR range (from 0.74 to 200 μm), coupled to variable angle transmittance and reflectance accessories that allow the characterization of the scattering properties of nonhomogeneous samples (laboratory planetary aerosol analogs, films, slabs of material, crystals, powders…) over a wide incidence and emittance angle range (0-90 degrees). This permits the angular light distribution in both transmission and reflection measurements to be characterized, enabling the determination of the complex indices of refraction, n and k, over the full NIR-FIR range via modeling of the laboratory observations. The resulting refractive indices are critical input parameters in radiative transfer models, exoplanet and brown dwarf cloud models, protoplanetary disk simulations and other models used for the interpretation of observational data from past, current and future (exo)planetary NASA missions. We will present preliminary data obtained on Titan aerosol analogs produced in the Titan Haze Simulation (THS) experiment on COSmIC, a unique experimental platform developed at NASA Ames that allows the simulation of Titan's complex atmospheric chemistry at Titan-like temperature (200 K). We will also introduce a new study of the optical properties of ammonium-bearing phosphates, potential cloud particles forming in temperate exoplanets and brown dwarfs.

Acknowledgements: The authors acknowledge the technical support of Emmett Quigley.

121.04 — Dust Evolution in the Late Stages of Planet Forming Disks

This is an additional presentation of abstract 105.06. See that entry for details.

122 — Stars & Stellar Topics I

122.01 — Effective Temperatures of Low-Mass Stars from High-Resolution H-band Spectroscopy

Ricardo Lopez-Valdivia[1]; Gregory N. Mace[1]; Kimberly R. Sokal[1]; Daniel Thomas Jaffe[1]

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High-resolution, near-infrared spectra will be the primary tool for finding and characterizing Earth-like planets around low-mass stars. Yet, the properties of exoplanets can not be precisely determined without accurate and precise measurements of the host star. Spectra obtained with the Immersion GRating INfrared Spectrometer (IGRINS) simultaneously provide diagnostics for most stellar parameters, but the first step in any analysis is the determination of the effective temperature. Here we report the calibration of high-resolution H-band spectra to accurately determine effective temperature for stars between 4000-3000 K (~K8 – M5) using absorption line depths of Fe, OH, and Al. The field star sample used here contains 254 K and M stars with temperatures derived using BT-Settl synthetic spectra. We use 106 stars with precise temperatures in the literature to calibrate our method with typical errors of about 140 K, and systematic uncertainties less than ~120 K. For the broadest applicability, we present T_{eff} – line-depth-ratio relationships, which we test on 12 members of the TW Hydrae Association and at spectral resolving powers between ~10,000–120,000. These ratios offer a simple but accurate measure of effective temperature in cool stars that is distance and reddening independent.

122.02 — Do Kepler superflare stars really include slowly-rotating Sun-like stars ? - Results using APO 3.5m telescope spectroscopic observations and Gaia-DR2 data -

Yuta Notsu[1,2]; Hiroyuki Maehara[3]; Satoshi Honda[4]; Suzanne L. Hawley[5]; James R. A. Davenport[5]; Kosuke Namekata[1]; Shota Notsu[1,6]; Kai Ikuta[1]; Daisaku Nogami[1]; Kazunari Shibata[1]

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Solar and stellar flares are the energetic explosions in the solar and stellar atmosphere, and superflares are very large flares that release total energy $10\sim10^4$ times greater than that of the biggest solar flares ($\sim10^{32}$ erg). Recent Kepler-space-telescope observations found more than 1000 superflares on a few hundred solar-type stars. We report the latest view of Kepler solar-type (G-type main-sequence) superflare stars, including recent updates with Apache Point Observatory (APO) 3.5m telescope spectroscopic observations and Gaia-DR2 data. First, more than half (43 stars) are confirmed to be "single" stars, among 64 superflare stars in total that have been spectroscopically investigated so far in this APO3.5m and our previous Subaru/HDS observations. The measurements of v sin i (projected rotational velocity) and chromospheric lines (Ca II H&K and Ca II 8542 A) support the brightness variation of superflare stars is caused by the rotation of a star with large starspots. Then, we investigated again the statistical properties of Kepler solar- type superflare stars by incorporating Gaia-DR2 stellar radius values. As a result, the maximum superflare energy continuously decreases as the rotation period Prot increases. Superflares with their energy $<\sim 5\times10^{34}$ erg would occur on old slowly-rotating Sun-like stars (P_{rot} ~25 days) once every 2000–3000 years, while young rapidly- rotating stars with P_{rot} ~ a few days have superflares up to 10^{36} erg. The maximum starspot area does not depend on the rotation period when the star is young rapidly- rotating, but as the rotation slows down, it starts to steeply decrease at P_{rot} ~12 days for Sun-like stars. These two decreasing trends can be consistent since the magnetic energy stored around starspots explains the flare energy, but other factors like spot magnetic structure should be also considered. These results presented in this work support that even slowly-rotating stars similar to the Sun can have large starspots necessary for superflares, considering long-term (1,000-10,000 years) activity level changes.

122.03 — Probing the Origins of Intense Magnetism in Early M-Dwarf Stars

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M-type stars are quickly stepping into the forefront as some of the best candidates in searches for habitable Earth-like exoplanets, and yet many M-dwarfs exhibit extraordinary flaring events which would bombard otherwise habitable planets with ionizing radiation. In recent years, observers have found that the fraction of M-stars demonstrating significant magnetic activity transitions sharply from roughly 10% for main-sequence stars earlier (more massive) than spectral type M3.5 (0.35 $M_\odot$) to nearly 90% for stars later than M3.5. Stellar dynamos are are driven primarily by fluid motions in the convection zone, the base of which migrates inward with decreasing stellar mass. Suggestively, it is also later than M3.5 at which main-sequence stars become fully convective, and may no longer contain a tachocline. This layer of rotational shear separating the convection and radiative zones is thought to play a significant role in solar magnetism, and so we here investigate its influence on M-dwarf dynamos. Using the spherical 3D MHD simulation code Rayleigh, we compare the convective flows, magnetic field configurations and generation, and time dependencies of dynamos operating within quickly rotating M2 (0.4 $M_\odot$) stars spanning a range of rotation rates and diffusivities, with the computational domain either terminating at the base of the convection zone or permitting overshoot into the underlying stable region. We find that a tachocline is not necessary for the organization of strong (10-20 kG) toroidal wreaths of magnetism in these stars, though its presence can increase the coupling of mean field amplitudes to the stellar rotation rate and in some cases drastically alter the character of the fields produced. Additionally, in stars that undergo periodic magnetic cycles, we find that the presence of a tachocline makes these cycles both longer and more regular than they would have otherwise been. Finally, we find that the tachocline helps to enhance the surface poloidal fields and organize them into larger spatial scales, both of which provide favorable conditions for more rapid angular momentum loss through a magnetized stellar wind.

122.04 — Double Trouble: Biases Caused by Binaries in Large Stellar Rotation Datasets

Gregory Vahag Aghabekian Simonian[1]
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The volume of stellar rotation data has expanded greatly due to the advent of large-scale spectroscopic and high-precision photometric time-domain surveys. However, the presence of binaries can bias the interpretation of stellar rotation in these datasets. I found that the rapid rotators in the Kepler field are consistent with being a background tidally-synchronized population, which would inflate the number of young stars interpreted through a single-star gyrochronology. By evaluating the quality of APOGEE spectroscopic v sini in the Kepler field, I discovered that spectral blending of equal luminosity binaries can mimic rotational broadening for velocity offsets near APOGEE's spectral resolution. This effect can dominate over true rapid rotators for old stellar populations. However, for systems where the luminosity of the secondary is negligible, I found that the APOGEE vsini are reliable. I will discuss strategies to improve the interpretations of rotation by either filtering likely binaries, or modeling their effects.

122.05 — Supergranulation on the Sun and stars: A simple model for its length scale

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Turbulent convection in stellar envelopes is critical to heat transport and dynamo activity. Modeling it well it has proven surprisingly difficult, and recent solar and stellar observations have raised questions about our understanding of the dynamics of both the deep solar convection and the mean structure of the upper layers of convective stellar envelopes. In particular, the amplitude of low wavenumber convective motions in both local area radiative magnetohydrodynamic and global spherical shell magnetohydrodynamic simulations of the Sun appear to be too high. In global simulations this results in weaker than needed rotational constraint of the motions and consequent non solar-like differential rotation profiles. In deep local area simulations it yields strong horizontal flows in the photosphere on scales much larger than the observed supergranulation, leaving the origin of the solar supergranular scale enigmatic. The problems are not confined to the Sun. Models of stellar convection show too sharp a transition to the interior adiabatic gradient, leading to a mismatch between computed and observed oscillation frequencies. We suggest that there is a common solution to these problems: convective motions in stellar envelopes are even more non-local than numerical models suggest. Small scale photospherically driven motions dominate convective transport even at depth, descending through a very nearly adiabatic interior (more nearly adiabatic in the mean than numerical models achieve). To test this, we develop a simple model that reproduces the mean thermodynamic stratification of three dimensional hydrodynamic stellar envelope models. It can recover the mean thermodynmaic states of the full models knowing only the filling factor and entropy fluctuations of the granular downflows in their photospheres. The supergranular scale of convection is then determined by the depth to which the presence of granular downflows alters the otherwise adiabatically stratified background. The supergranular scale of convection is then determined by the depth to which the presence of granular downflows alters the otherwise adiabatically stratified background.

122.06 — Nonlinearly damped oscillation modes in red giants

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Turbulent motions in the convective envelope of red giants excite a rich spectrum of solar-like oscillation modes. Observations by CoRoT and Kepler have shown that the mode amplitudes increase dramatically as the stars ascend the red giant branch, i.e., as the frequency of maximum power, $\nu_{\rm max}$, decreases. Most studies nonetheless assume that the modes are well described by the linearized fluid equations. We investigate to what extent the linear approximation is justified as a function of stellar mass M and $\nu_{\rm max}$, focusing on dipole mixed modes with frequency near $\nu_{\rm max}$. A useful measure of a mode's nonlinearity is the product of its radial wavenumber and its radial displacement, $k_r\xi_r$ (i.e., its shear). We show that $k_r\xi_r \propto \nu_{\rm max}{}^{-9/2}$, implying that the nonlinearity of mixed modes increases significantly as a star evolves. The modes are weakly nonlinear ($k_r\xi_r > 10^{-3}$) for $\nu_{max} < 150$ μHz and strongly nonlinear ($k_r\xi_r > 1$) for $\nu_{\rm max} < 30$ μHz, with only a mild dependence on M over the range we consider (1.0 - 2.0 $M_\odot$). A weakly nonlinear mixed mode can excite secondary waves in the stellar core through the parametric instability, resulting in enhanced, but partial, damping of the mode. By contrast, a strongly nonlinear mode breaks as it propagates through the core and is fully damped there. Evaluating the impact of nonlinear effects on observables such as mode amplitudes and linewidths requires large mode network simulations. We are currently carrying out such calculations and investigating whether nonlinear damping can explain why some red giants exhibit dipole modes with unusually small amplitudes, known as depressed modes.

122.07 — Predictions for Upcoming Recurrent Novae Eruptions; T CrB in 2023.6±1.0, U Sco in 2020.0±0.7, RS Oph in 2021±6, and more

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The prediction of upcoming recurrent nova eruptions has good utility for promoting a frequent watch so that the usually-very-short eruptions are not missed and caught early, plus allowing for the pre-organization of intense observing campaigns. Such efforts are highlighted by my prediction of the 2010 eruption of U Sco, where spacecraft targets-of-opportunity programs were in place in advance and workers watched the target several times a day for over a year, then resulting in measured magnitudes averaging every three minutes for the entire eruption, plus daily and hourly spectra and UBVRIJHK photometry, plus X-ray, gamma-ray, far-IR, IR, and UV spacecraft observations, leading to the all-time best observed nova eruption and the discovery of two new phenomena. Recurrent novae are a particularly important subset of all novae, and they have the advantage that their eruptions can be predicted with useable accuracy. Inter-eruption times can be predicted from the brightness during quiescence, and by looking at the history of inter-eruption intervals. For T CrB, with eruptions in 1866 and 1946, a simple constancy of interval suggests the next eruption will be in 2026. But a better prediction is based on the pre-eruption-plateau with a rise to the plateau from 1936.0-1939.6 before the fast 1946.1 eruption, so with T CrB showing the same rise from 2014.2-2016.4 up to the current plateau, the next eruption will be in 2023.6±1.0. For the long history of intervals for U Sco (averaging 10.6 years), the next eruption should come in 2020.7±1.6. But U Sco was substantially bright in 2011-2012, with higher accretion, so it should accumulate the trigger mass substantially before 2020.7. Given that it has not erupted as of this writing, I predict a date of 2020.0±0.7. For RS Oph, based on its rather variable intervals, the next eruption should start in 2021±6. V394 CrA, CI Aql, V3890 Sgr, and V2487 Oph should go off any year now, but there is no high confidence for setting a date.

123 — Cosmological Probes of Dark Matter II

123.01 — Placeholder: Celine Boehm

123.02 — Early Structure Formation in LPBH Cosmologies

Derek Inman[1]; *Yacine Ali-Haimoud*[1]
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Primordial black holes (PBH) comprising some fraction of the Universe's dark matter is a potentially interesting alternative to the more standard particle based dark matter. If the fraction is large, PBHs can significantly alter how and when nonlinear structures develop. If it is small, they could provide potentially interesting constraints on WIMPs and/or seed the super massive black holes known to exist by redshift ~7. We have run LPBH cosmological simulations of structure formation starting from deep in the radiation era and ending at z=100. We analyze the clustering, structure and mass function of halos in the simulation, as well as typical PBH velocities relevant for CMB constraints. Future use cases include tidal perturbations on primordial PBH binaries and whether the formation of stars differs in this scenario.

123.03 — Probing the nature of dark matter with astrophysical and gravitational waves observations

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The formation and growth of black holes inevitably modifies the dark matter distribution around them. If dark matter is in the form of self-annihilating weakly interacting massive particles (WIMPs), the increase in dark matter density can significantly boost the annihilation rate. In the case of primordial black holes (PBHs), a stringent constraints on their cosmological abundance has been obtained by comparing the gamma-ray background produced by WIMP annihilations around them with the one observed by Fermi-LAT. Here, we take the opposite viewpoint. We focus on the prospects for discovering PBHs with upcoming radio and gravitational waves searches, and on the implications such a discovery would have on even a small relic density of WIMPs in the Universe. Specifically, we consider three discovery scenarios: 1) The detection of gravitational waves produced by the merger of subsolar BHs with LIGO/Virgo; 2) The detection of gravitational waves produced by the merger of O(10) solar mass BHs at redshift z > 40 with the Einstein telescope; 3) The detection of the radio emission produced by the accretion of gas onto 1000 solar mass BHs with the Square Kilometer Array. We estimate the abundance of PBHs in each scenario, and, from that, we calculate the gamma-ray luminosity of WIMP overdensities around PBHs in the Milky Way. By comparing it with the observed diffuse extragalactic gamma-ray flux and with unidentified gamma-ray point sources in the 3FGL Fermi catalogue, we show that a positive detection of even a small number of PBHs in any of the above scenarios would set extraordinarily stringent constraints on weak-scale extensions of the Standard Model, including those predicting a WIMP abundance much smaller than that of dark matter, ruling out almost the entire parameter space of popular theories like the so-called MSSM7, GUT-scale SUSY and scalar singlet scenarios. If time allows, I will also discuss complementary constraints on the particle nature of dark matter arising from the analysis of stellar streams.

123.04 — The Early Universe's Imprint on Dark Matter

Adrienne L. Erickcek[1]; M. Sten Delos[1]; Carisa Miller[1]; Kayla Redmond[1]
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As remnants of the earliest stages of structure formation, the smallest dark matter halos provide a unique probe of the density fluctuations generated during inflation, the evolution of the Universe shortly after inflation, and the origins and properties of dark matter. The absence of early-forming ultracompact minihalos (UCMHs) establishes an upper bound on the amplitude of the primordial power spectrum on small scales and has been used to constrain inflationary models. Numerical simulations of UCMH formation reveal that these constraints need to be revised because the dark matter annihilation rate within UCMHs is lower than has been assumed. Nevertheless, minihalos can still provide unrivaled constraints on the small-scale primordial power spectrum because dark matter annihilation within later-forming minihalos more than compensates for the dimished rate within UCMHs. The abundance of minihalos also encodes information about the evolution of the Universe prior to Big Bang nucleosynthesis (BBN). Deviations from radiation domination prior to BBN can enhance the minihalo poputation, thereby boosting the dark matter annihilation rate within dwarf spheroidal galaxies if dark matter is a thermal relic. Conversely, the nonthermal production of dark matter can suppress the small-scale power spectrum. It is therefore possible to use gamma-ray observations and observations of the Lyman-α forest to learn about the origins of dark matter and the evolution of the Universe during its first second.

124 — Galaxies

124.01 — What's lighting up the Magellanic Stream?

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Galaxy interactions have greatly disturbed and redistributed the gas in the Magellanic System throughout the halo of the Milky Way. Using the Wisconsin H-α Mapper (WHAM) telescope, we have completed the highest sensitivity and kinematically resolved emission-line survey of the entire Magellanic Stream. These observations enable us to determine how the ionization conditions change over 100 degrees across the sky, including the region below the South Galactic Pole. We explore the sources of that ionization and find that photoionization from the

Milky Way and Magellanic Clouds is insufficient to explain the observed H-α emission. We further investigate whether halo-gas interactions, self ionization through a "shock cascade" that results as the Stream plows through the halo, and energetic processes associated with the Milky Way's center could be responsible for the ionization. The gas in the Magellanic Stream could supply enough gas to maintain or even boost the star formation in the Milky Way, but only if it can survive the journey to the Galaxy's disk.

124.02 — Multi-wavelength Study of Spiral Structure and Star-Formation Region in Disk Galaxies

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The density-wave theory of spiral structure proposes that star formation occurs in or near a spiral-shaped region of higher density that rotates rigidly within the galactic disk at a fixed pattern speed. In most interpretations of this theory, newborn stars move downstream of this position as they come into view, forming a downstream spiral which is tighter, with a smaller pitch angle than that of the density-wave itself. Rival theories, including theories which see spiral arms as essentially transient structures, may demand that pitch angle should not depend on wavelength. We measure the pitch angle of a large sample of galaxies at several wavelengths associated with star formation or very young stars (8.0 microns, H-α line and 151 nm in the FUV) and show that they all have the same pitch angle, which is larger than the pitch angle measured for the same galaxies at optical and NIR wavelengths. Our measurements in the B-band and at 3.6 microns have unambiguously tighter spirals than the star-forming wavelengths. In addition, we have measured in the u-band, which seems to fall midway between these two extremes. Thus our results are consistent with a region of enhanced stellar light situated downstream of a star-forming region.

124.03 — Evidence in favor of Density Wave Theory, through multiwavelength image analysis, spatially resolved stellar clusters and star formation history maps

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Stationary density wave theory, originally proposed by C.C. Lin and Frank Shu (Lin & Shu 1964), explains the nature and the origin of spiral arm structures in galaxies as density waves which propagates through the galactic disk. It predicts the existence of an age gradient across the spiral arm with a change in the age gradient direction at the co-rotation radius. Using an image overlaying technique we were able develop a method for identifying the co-rotation radius. By considering spatially resolved stellar clusters of different ages and by analyzing star formation history maps we have found compelling results in favor of Density Wave Theory. We have derived star-formation history (SFH) maps with LIGHTNING (Eufrasio et al. 2017) spectral energy distribution (SED) fitting procedure, which incorporated photometric data from GALEX, Swift, SDSS, 2MASS, Spitzer, WISE, and Herschel. The SFH were derived non-parametric bins of 0–10Myr, 10–100Myr, 0.1–1Gyr, 1–5Gyr, and 5–13.6Gyr. The dynamic evolution of spiral arms can be traced by observing these stellar cluster maps and SFH maps. They can be quantified by tracing spiral arms, measuring pitch angles and also by observing the azimuthal offsets relative to the dust lanes. 8µm, Infrared Spitzer images were used as a tracer for dust lanes, hence depicting the maximum intensity locations of the density wave.

124.04 — (withdrawn)

This abstract was withdrawn.

124.05 — Low-Luminosity Core Dominated Radio Galaxies and the Extragalactic Gamma-Ray Background

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Recent surveys have revealed a large number of low-luminosity core dominated radio galaxies that are much more abundant than those at higher luminosities. These objects will be too faint in gamma-rays to be detected individually by Fermi. Nevertheless, they may contribute significantly to the unresolved extragalactic gamma-ray background (EGB). We consider the possible contribution of this population to the EGB. Using available data available for 45 radio galaxies listed as gamma-ray detected counterparts we have searched radio maps which can resolve the core flux from the total source flux. We were able to obtain core fluxes for virtually every source which we then used to derive a relation between core radio flux and gamma-ray flux. We then extrapolated to low radio luminosities where the predominant population is apparently highly core dominated. Employing a very recent determination of the luminosity function for core dominated radio galaxies we estimate the contribution of all possible gamma-ray emitting radio galaxies to the unresolved extragalactic gamma-ray background. We find this contribution to be a possibly non-negligible, 4% - 18%.

124.06 — Dry/mixed galactic interactions do not trigger star formation

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We investigate star formation (SF) in interacting galaxies, focusing on the impact of neighbors. Galaxies in pairs are selected from the Sloan Digital Sky Survey. We classify the pairs into two groups according to the SF activity of the neighbor, namely (i) ones with a quiescent neighbor and (ii) ones with a star-forming neighbor. We carefully build control samples of isolated galaxies by matching the redshift, stellar mass, and local density. We find that SF of galaxies paired with a star-forming neighbor is more enhanced than the control sample, consistent with other studies. More interestingly, however, we unexpectedly find no enhancement of SF in interactions with a quiescent neighbor. This opposes the conventional view that galactic interactions lead to bursts of SF. We propose that gas richness of neighbors is a critical factor for triggering SF even during the "pair" stages of mergers. We discuss possible mechanisms to explain the observed trends.

124.07 — A *WISE* Determination of the Contribution of Galaxies to the Extragalactic Background Light at 3.4 μm

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The study of the extragalactic background light (EBL) in the optical and near infrared has received a lot of attention in the last decade, especially near a wavelength of $\lambda \approx 3.5$ μm, with remaining tension among different techniques for estimating the background. We use measurements of the mean spectral energy distribution (SED) and luminosity function of galaxies optimized for this purpose to produce new estimates of the contribution of galaxies to the EBL at 3.4 μm using *WISE* W1 photometry. Our results are consistent with extant measures, though a little higher than most. The source of the tension is how the luminosity function and mean SED evolves at high redshifts ($z > 1$).

125 — Solar Physics Division Meeting (SPD), Corona 2

125.01 — A Comprehensive Assessment of EUV Polar Coronal Holes: 1996 — 2018

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Polar Coronal Holes are the longest-lived features on the sun and are a critical piece to understand the global state of the solar corona. Because of the oblique viewing angle, obstruction due to the coronal plasma scale height, and lack of ground truth make segmentation of polar holes difficult. We make new measurements of polar hole's perimeter and area in three EUV wavelengths between 1996 and 2018 using five different space-based imagers: SOHO EIT, STEREO A and B EUVI, PROBA2 SWAP, and SDO AIA. The generated time-series of coronal hole parameters rarely agree with each other, which presents a difficult data problem: multi-band, multi-instrument, heteroscedastic measurements with periodic and systematic signals. We combine these measurements using a parametric bootstrap method to make an empirical estimation of the polar coronal hole's size, boundary, and center of mass. This technique allows us to simultaneously analyze the physical properties of polar coronal holes and identify regular periodicities in our data from other origins. We present a comprehensive view of the EUV polar coronal hole over the past 22 years.

125.02 — Coronal Condensation at Preferential Topological Locations: The Birth of Solar Prominences and Coronal Rain

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The million-degree hot and tenuous solar coronal plasma, under certain conditions, can enigmatically undergo a radiative cooling instability and condense into material of 100 times cooler in the form of prominences or coronal rain. Where, when, and how such cooling condensation takes place remain poorly understood. Answers to these questions are not only of scientific importance in their own right, but also bear implications for the fundamental question of coronal heating and the chromosphere-corona mass cycle. Magnetic fields in the magnetized corona undoubtedly play a crucial role (e.g., by trapping the plasma), but where and how? We report recent imaging and spectroscopic observations from SDO/AIA/HMI and IRIS that can shed light on these puzzles. Through a systematic survey, we found that a large fraction of quiet-Sun condensations preferentially occur at the dips of coronal loops or funnels. Such dips are located at/near magnetic topological features, such as null points and quasi-separatrix layers (QSLs), which are regions characterized by high values of the squashing factor. We also identified evidence of magnetic reconnection at such locations, which can produce favorable conditions, e.g., density enhancement by compression and/or mass trapping in plasmoids, that can trigger run-away radiative cooling. We will discuss the significance and broader implications of these novel observations.

125.03 — Fluxon Modeling of CMEs and the Steady Solar Wind

Chris Lowder[1]; Derek Lamb[1]; Craig DeForest[1]

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The Field Line Universal relaXer (FLUX) code provides a framework for modeling the evolution of the solar coronal magnetic field through the use of fluxon structures. Each fluxon represents a piecewise-linear analogue for magnetic field lines, and carries a finite quantity of magnetic flux. Appropriate forces are computed and applied at vertex points along each fluxon, allowing for relaxation to an equilibrium state. For a given initial configuration, this allows for the study of fieldline topology and subsequent evolution. The nature of the FLUX model allows for enhanced efficiency when compared with grid-based MHD models, and avoids numerical reconnection issues. We describe recent enhancements to the FLUX code, including work with data assimilation, calculation of steady solar wind solutions, and CME eruption triggering.

125.04 — The Correlation Between The Enhanced Sulfur Abundance in Slow Solar Winds and The Magnetic Field Geometry of Their Source Regions

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We present an examination of the First Ionization Potential (FIP) fractionation scenario by the ponderomotive force in the chromosphere by using observations from The Solar Wind Ion Composition Spectrometer (SWICS) on board The Advanced Composition Explorer (ACE). Based on the prediction of the ponderomotive force model by Laming et al. (2019) that the abundance enhancements of intermediate FIP elements, S, P, and C, in slow solar wind can be explained by the release of plasma from strong open fields, much stronger than those usually associated with fast wind source regions, we examine the possible correspondence between the enhanced fractionation of intermediate FIP elements in slow solar winds and the magnetic field strength of their source regions. We do so by surveying the extensive record of solar wind speeds and composition from the ACE mission, and investigating the magnetic feature on the Sun associated with the repeated sulfur abundance anomaly corresponding to the decrease in the solar wind speed, found over about four solar rotation cycles in the beginning of 2008. We also obtain rough profiles of the magnetic field strength at the source regions of these slow winds, estimate the fractionation values of various elements using the ponderomotive force model with the field profiles as inputs, and compare the results with the observed fractionation values.

125.05 — Quantitatively Comparing WSA Coronal and Solar Wind Model Predictions with Observations Using ADAPT Input Maps

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Reliable estimates of the global solar photospheric magnetic field distribution are critical to accurately model and understand solar and heliospheric magnetic fields. The Air Force Data Assimilative Photospheric flux Transport (ADAPT) model generates synchronic (i.e., globally instantaneous) maps by evolving observed solar magnetic flux using relatively well understood transport processes when measurements are not available and then updating modeled flux with new observations using data assimilation methods that rigorously take into account model and observational uncertainties. ADAPT has recently been upgraded so that it now uses reverse active region (RAR) modeling, which is a process to include active regions that emerged on the far-side of the Sun and smoothly evolve them forward in time onto the visible disk. This paper compares Wang-Sheeley-Arge (WSA) coronal and solar wind modeling results at Earth and STEREO A & B using ADAPT RAR input model maps for the time interval of June-July 2010, when the active region (AR11087) emerged on the far-side of the Sun. Driven by global maps with and without RARs, we test the sensitivity of the WSA model results, as well as the effects of both enhancing and reducing the net flux in AR11087. We also present a newly developed method for quantitatively ranking ADAPT map realizations based on well the ADAPT driven WSA predictions agree with spacecraft observations.

125.06 — Understanding uniturbulence: self-cascade of MHD waves in the presence of inhomogeneities

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It is a generally accepted fact in the MHD turbulence community that the nonlinear cascade of wave energy requires the existence of counter-propagating Alfvénic wave-packets, along some mean magnetic field. This fact is an obvious outcome of the MHD equations when assuming an incompressible and homogenoeus plasma. There have been relatively few attempts to relax these assumptions in the context of MHD turbulence studies. However, it should be clear that once these assumptions brake down, the generally accepted picture of turbulent cascade generation is not universal. In the context of longitudinally stratified plasmas (i.e. gravitationally stratified coronal holes), it has been known since the 70's that inhomogeneities along the mean magnetic field lead to the linear coupling of sunward and anti-sunward propagating waves. This leads to co-propagating disturbances of Elsasser fields, which can interact coherently to initiate a nonlinear cascade. The alternative case of perpendicular inhomogeneity (across the mean magnetic field) was even less studied in the context of MHD turbulence. In this study we show that these type of inhomogeneities lead also to co-propagating Elsasser fields, already in the incompressible case. We show how the nonlinear self-deformation of these unidirectionally propagating waves leads to a cascade in k-space across the magnetic field. The existence of this type of unidirectional cascade might have an additional strong effect on the turbulent dissipation rate of dominantly outward propagating Alfvénic waves in structured plasma, as in solar coronal holes.

126 — Solar Physics Division Meeting (SPD), Instrumentation

126.01 — The Chromospheric Layer Spectro-Polarimeter (CLASP2) Sounding Rocket Mission: First Results

David Eugene McKenzie[1]; Ryohko Ishikawa[2]; Ryouhei Kano[2]; Laurel Rachmeler[1]; Javier Trujillo Bueno[3]; Ken Kobayashi[1]; Donguk Song[2]; Masaki Yoshida[2]; Frederic Auchere[4]; Takenori Okamoto[2]

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A major challenge for heliophysics is to decipher the magnetic structure of the chromosphere, because of its vital role in the transport of energy into the corona and solar wind. Routine satellite measurements of the chromospheric magnetic field will dramatically improve our understanding of the chromosphere and its connection to the rest of the solar atmosphere. Before such a satellite can be considered for flight, we must refine the measurement techniques by exploring emission lines with a range of magnetic sensitivities. In 2015, CLASP achieved the first measurement of linear polarization produced by scattering processes in a far UV resonance line (hydrogen Lyman-α), and the first exploration of the magnetic field (via the Hanle effect) and geometrical complexity in quiet regions of the chromosphere-corona transition region. These measurements are a first step towards routine quantitative characterization of the local thermal and magnetic conditions in this key layer of the solar atmosphere.

Nonetheless, Lyman-α is only one of the magnetically sensitive spectral lines in the UV spectrum. CLASP2 extends the capability of UV spectropolarimetry by acquiring ground-breaking measurements in the Mg II h and k spectral lines near 280 nm, whose cores form about 100 km below the Lyman-α core. These lines are sensitive to a larger range of field strengths than Lyman-α, through both the Hanle and Zeeman effects. CLASP2 will capture measurements of linear and circular polarization to enable the first determination of all 4 Stokes parameters in chromospheric UV radiation. Coupled with numerical modeling of the observed spectral line polarization (anisotropic radiation pumping with Hanle, Zeeman and magneto-optical effects), CLASP2 is a pathfinder for determination of the magnetic field's strength and direction, as well as of the geometry of the plasma in the upper solar chromosphere.

CLASP2 will launch from White Sands Missile Range in April 2019. In this presentation, we will summarize the characteristics of the CLASP2 flight, the performance of the UV telescope and spectropolarimeter, and our preliminary findings.

126.02 — The FOXSI-3 rocket: Overview and early results of its latest flight

Juan Camilo Buitrago-Casas[1]; Lindsay Glesener[2]; Sasha Courtade[1]; Juliana Vievering[2]; Subramania Athiray Panchapakesan[3]; Sophie Musset[2]; Daniel Ryan[4]; Gregory Dalton[1]; Shin-Nosuke Ishikawa[5]; Noriyuki Narukage[6]; Stephen Bongiorno[3]; Kento Furukawa[5]; Lance Davis[2]; Paul Turin[1]; Zoe Turin[7]; Tadayuki Takahashi[5]; Shin Watanabe[5]; Sam Krucker[1]; Steven Christe[4]; Brian Ramsey[3]

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Hard X-rays (HXRs) from the solar corona are closely connected to energy releases and particle transport in solar flares of all sizes. Expressly, faint solar HXR emissions are of remarkable interest in understanding solar flare structure and dynamics. This is because of their connection with, for instance, loop top emission and small flares. Mainly due to the indirect imaging methods used by past solar-dedicated HXR imagers, like RHESSI, faint HXRs observations have been limited by the imaging dynamic range and sensitivity of the instruments.

The Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket payload is the first solar-dedicated instrument designed for performing imaging spectroscopy in the 4-20 keV range by using direct focusing optics. FOXSI has successfully flown three times from the White Sands Missile Range in New Mexico. For its latest rocket campaign (FOXSI-3), an enhanced version of the experiment, which includes optics and detector upgrades, was implemented for the launch which happened on September 7, 2018. In this talk, we present an overview of the FOXSI-3 campaign, describing in detail the improved capabilities of the telescope and how they allow for better

investigation of faint coronal HXRs. We also present a preliminary analysis of the FOXSI-3 observations.

126.03 — Satellite mission: PhoENiX (Physics of Energetic and Non-thermal plasmas in the X (= magnetic reconnection) region)

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We are studying a new solar satellite mission, "PhoENiX", for understanding of particle acceleration during magnetic reconnection, which are ubiquitous features exhibited by a wide range of plasmas in the universe. The main observation targets of this mission are solar flares that are caused by magnetic reconnection and accelerate plasma particles. The sun is a unique target in the sense that it can be investigated in great detail with good spatial, temporal and energy resolutions. The scientific objectives of this mission are (1) to identify particle acceleration sites, (2) to investigate temporal evolution of particle acceleration, and (3) to characterize properties of accelerated particles, during magnetic reconnection, i.e., during solar flares. In order to achieve these science objectives, the PhoENiX satellite is planned to be equipped with three instruments of (1) Photon-counting type focusing-imaging spectrometer in soft X-rays (up to ~10 keV) demonstrated by FOXSI-3, (2) Photon-counting type focusing-imaging spectrometer in hard X-rays (up to ~30 keV) like FOXSI series, and (3) Spectropolarimeter in soft gamma-rays (spectroscopy is available in the energy range of from > 20 keV to < 600 keV; spectropolarimetry is available from > 60 keV to < 600 keV) like Hitomi/SGD. We plan to realize this satellite mission around next solar maximum (around 2025). In this presentation, we will explain the details of science goal, science objectives and instruments of PhoENiX mission. Additionally, in order to demonstrate the unprecedented observations with PhoENiX, we will show the soft X-ray photon-counting data taken by FOXSI-3 sounding rocket.

126.04 — Science Mission of a Neutrino Space-craft

Nickolas Solomey[1]
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The development of a Neutrino Detector that can be operated in Space would result in the ability to do several major science investigations. Presented here is a detector concept that has been developed as part of the NASA Innovation Advanced Concept program in 2018/19 and how it can be expanded upon to do Science. The basic idea is that by going closer to the Sun the intensity of Solar Neutrinos will go up by factors of thousands, but in addition to this a space-craft can go off the ecliptic plane to view the Sun at high latitudes and even the polar region which could do unique studies of the Solar core that cannot be done on Earth. The Sun can also act as a Gravitational Lens with millions of time light collecting power and the Neutrino Gravitational Lens which is much closer to the Sun at 25 AU than the light Gravitational Focus is reachable with current rocket launch technology. Other than the Sun the largest neutrino source in the night sky would be the Galactic core and it can be imaged as a space craft transversing the Neutrino Gravitational Lens focus to study the structure of the Galactic core. There is even the possibility to study Dark Matter with a space-craft with a neutrino detector since solar neutrinos are a background and this background could be changed as a flight trajectory takes the detector mounted space-craft to different solar radii distances. These new ideas are under study to see the total science potential of such a program.

126.05 — Photon sieves and the future of EUV imaging spectroscopy

Adrian N. Daw[1]*; Douglas M. Rabin*[1]*; Donald James Schmit*[1]*; Kevin Denis*[1]
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Large-aperture photon sieves fabricated at NASA-GSFC can provide diffraction-limited imaging at EUV and X-ray wavelengths, that is, spatial scales down to milli-arcseconds, and are also being used to provide monochromatic, collimated beams for the calibration of solar EUV instruments such as the Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS). EUNIS is a two-channel imaging spectrograph with unprecedented dynamic range and broad spectral coverage (9-11 nm and 52-64 nm), scheduled for a sounding rocket flight in September 2019. This will be the first time the 9-11 nm wavelength range of the Sun has ever been observed by an imaging spectrograph, despite the importance of these short EUV/soft X-ray wavelengths to observing the hottest (>5MK) plasma in the non-flaring atmosphere, which is critical to understanding the energization of the solar corona. Recent results will be presented, and capabilities for future solar EUV missions will be discussed.

126.06 — TSMM - A Tomographic Solar Magnetism Mission

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Detailed knowledges of the magnetic and thermal environment of the solar atmosphere, including the photosphere, chromosphere, and the corona, and how the plasma and the magnetic fields interact with each other, are crucial for the understanding of the physics of solar eruptions, which directly influences space weather in interplanetary space. However, the inference of the 3D coronal vector magnetic fields from observations is not straightforward due to the complex nature of the emission process (resonance scattering through Hanle and Zeeman effects) and line-of-sight (LOS) integration through the optically thin corona. Recent progresses in spectropolarimetric measurements of the polarized spectra of magnetically sensitive corona emission lines and their interpretation, and the development of tomographic inversion techniques now provides a viable path toward quantitative characterization of the 3-dimensional coronal temperature, density, and magnetic field structures.

Tomographic inversion relies on observations of the object under study from multiple sight lines. For earth-bound observers, tomographic inversion of the static temperature, density, and magnetic fields structures can be realized using pseudo tomographic observations due to the rotation of the sun. However, to resolve the temporal evolution of the structures of the solar atmosphere before, during, and after solar eruptions, a space mission consisting of multiple spacecraft deployed in deep space circumsolar orbits is needed to observe the sun from many sight lines simultaneously. This paper describes recent progresses in tomographic inversion techniques, and an instrument development effort to develop compact and high-performance instrumentation that will enable the deployment of a deep-space tomographic solar magnetism mission in the near future.

127 — George Ellery Hale Prize Lecture: Observations about Observations of the Sun, Philip Scherrer (Stanford University)

127.01 — Observations about Observations of the Sun

Philip H. Scherrer[1]
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After more than 50 years as an observer of the Sun, of the process of observing the Sun, and of the people who participate in the adventure I will offer some comments about what I have learned.

128 — iPoster Plus III: Dust & Star Formation

128.01 — Spinning Dust Emission from Circumstellar Disks and Its Role In Excess Microwave Emission

Lan Quynh Nguyen[1]*; Thiem Hoang*[2]*; Vinh Nguyen*[3]*; Grant James Mathews*[1]
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Electric dipole emission from rapidly spinning polycyclic aromatic hydrocarbons is widely believed to be an origin of anomalous microwave emission, but recently it has encountered a setback owing to the noncorrelation of anomalous microwave emission with polycyclic aromatic hydrocarbon abundance seen in a full-sky analysis. Microwave observations for specific regions with well-constrained polycyclic aromatic hydrocarbon features would be crucial to test the spinning dust hypothesis. In this paper, we present physical modeling of microwave emission from spinning polycyclic aromatic hydrocarbons from protoplanetary disks around Herbig Ae/Be stars and T Tauri stars where polycyclic aromatic hydrocarbons features are well observed. Guided by the presence of 10 μm silicate features in some protoplanetary disks, we also model microwave emission from spinning nanosilicates. Thermal emission from big dust grains is computed using the Monte Carlo radiative transfer code. Our

numerical results demonstrate that microwave emission from either spinning polycyclic aromatic hydrocarbons or spinning nanosilicates dominates over thermal dust at frequencies $\nu < 60$ GHz, even in the presence of significant grain growth. Finally, we attempt to fit millimeter-centimeter observational data with both thermal dust and spinning dust for several disks around Herbig Ae/Be stars that exhibit polycyclic aromatic hydrocarbon features and find that spinning dust can successfully reproduce the observed excess microwave emission. Future radio observations with ngVLA, SKA, and ALMA Band 1 would be valuable for elucidating the origin of excess microwave emission and potentially open a new window for probing nanoparticles in circumstellar disks.

128.02 — A Comparison between Magnetic Field Directions Inferred from Planck and Starlight Polarimetry toward Gould Belt Clouds

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We compare the magnetic field (B-field) orientations inferred from Planck 353 GHz thermal dust polarization and starlight polarimetry data and study the cloud-field alignment based on these two tracers within Gould Belt clouds, which show good agreement with each other. Furthermore, we analyze two fundamentally different alignment studies—global (cloud scale, ∼ 10-100 pc) cloud-field alignment, which compares mean fields and global cloud orientations, and local (pixel size scale, ∼ 0.1-1 pc) structure-field alignment, which compares this relation pixel by pixel—and find the connection between them.

129 — iPoster Plus IV: Extrasolar Planets

129.01 — SISTER: Starshade Imaging Simulation Toolkit for Exoplanet Reconnaissance

Sergi R. Hildebrandt[1,2]; Stuart Shaklan[1]; Margaret C. Turnbull[3,1]; Eric Cady[1]
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We have developed a suite of software forming an end-to-end starshade imaging tool that produces images of an arbitrary user-defined exoplanetary system and background as observed by a starshade and a telescope. The starshade imaging characteristics include both the diffraction from an ideal or perturbed starshade as well as solar glint from the starshade edges, the largest source of local instrument scatter. The telescope model assumes an ideal telescope with a user-defined obscured pupil (e.g. secondary obstruction and struts). It incorporates a vanilla detector model with read noise and dark current. Finally, the astrophysics scenario incorporates Keplerian orbits, phase angles, geometric albedo, different atmospheric scattering/absorption laws, any kind of host star (by default the user can choose among any of the +10,000 stars from ExoCat) and a large variety of extragalactic background fields (galaxies, Quasars). Exodust emission is accurate for a solar system and flexible for an arbitrary user-defined profile. As a result, it can virtually build a large variety of extra-solar systems with an arbitrary number of exoplanets of multiple types and any host star, adding an optional background field, to obtain a series of images throughout the proposed mission. Proper motion and parallax are also taken into account when background fields are added to the simulated images. There are default systems, like the Solar System at any distance from us. We have employed the tool to support WFIRST-S, HabEx, and other mission probe studies and ground telescope concepts.

130 — iPoster Plus V: Cosmology & Related Topics

130.01 — Local IGM/CGM Diffuse Emission Constraints with HST+COS

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The Cosmic Origins Spectrograph (COS) onboard the Hubble Space Telescope (HST) has observed thousands of Lyman-α (Lyα) forest absorbers with both the G130M grating ($0< z < 0.19$) and the G160M grating ($0.14 < z < 0.48$). In this research, we use the 2D nature of the COS FUV MCP detectors to constrain the Lyα emission associated with Lyα absorbers. We will divide our Lyα absorber sample based upon proximity to the closest known galaxy to differentiate emission between intergalactic (IGM) and circumgalactic (CGM) regions. We will discuss the limits of these constraints/detections in terms of both cosmological implications and from a technological standpoint of a future mission.

130.02 — Constraints on the intensity of intergalactic magnetic fields with gamma-ray and radio observations of BL Lac-type blazars

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The observed magnetic fields in galaxies and galaxy clusters are believed to result from dynamo amplification of weak magnetic field seeds whose origin remains a long-standing open question. These seed magnetic fields will still be present in the intergalactic medium. Beams of TeV gamma-rays from blazar jets can be used to infer the intensity, coherence length, and helicity of the intergalactic magnetic field. Intergalactic magnetic fields deflect the electron-positron pairs produced by TeV gamma-rays from blazars, resulting in broadened beams of secondary GeV gamma-rays known as pair halos. Such pair-cascades develop along the projected direction of the blazar jet, which is known from imaging radio observations. We present a novel search for for GeV pair haloes that combines Fermi-LAT gamma-ray data around 12 high-synchrotron-peaked BL Lacs with well-determined jet orientation from VLBA radio observations. Our study exploits the expected asymmetry of blazar pair haloes and uses advanced simulations of the pair cascades to improve the sensitivity of previous studies and increase the signal to noise. Although we find no significant detection, a 2σ hint for an extended pair halo along the direction of the jet appears in the stacked gamma-ray data, corresponding to an intergalactic magnetic field with strength of about 10^{-15} Gauss. We will present the results of our analysis and discuss the limitations of pair-halo searches due to astrophysical uncertainties. Finally, assuming that the apparent convergence on B $\sim 10^{-15}$ G is not coincidental, we will outline a clear path towards a positive detection of blazar pair haloes with future space-borne and ground-based gamma-ray observatories.

130.03 — (withdrawn)

This abstract was withdrawn.

131 — iPoster Session: Education & History

131.01 — Precession Resolution Would Realize Aquarius Equinox Epoch

Steve Durst[1]
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The arrival and ascendance of the Aquarius Equinox Epoch continues to be widely considered and calculated using Earth Precession analytics. With the approach to J2000.0 / New Millennium from the 1960s / 1970s especially, astrophysics and astrometry scientists have been focusing intensely on Earth Precession rates and expressions. The science community interest in what Copernicus called 'Earth's 3rd Motion' has been complemented by the rise of public interest in precessional archeoastronomy.

Work on Precession and Rotation of the Earth has accelerated since 1930, when the 88 constellations and their boundaries – fixed by Delporte along strict lines of declination and right ascension as they existed at epoch 1875.0 – finally became ratified and published by the International Astronomical Union (IAU). Notable studies include, Lieske, IAU 1976 Precession Model (1977); Williams, Cartographic Coordinates and Rotational Elements (1994); Capitaine, IAU2000 Precession-Nutation Model and IAU2006 Precession Possible Upgrade (2017); Mathews, IAU2000A/B (2002); Fukushima, A New Precession Formula (2003); Zhu, Earth Rotation Parameters from VLBI (2017).

This work on higher rotation / precession accuracy may help more precisely determine the apparent arrival of the Sun on the ecliptic in the constellation of Aquarius at the time of the March equinox, which is now calculated about 2597 AD using the IAU 1928 / current sky map. Constellations and their boundaries are the results ultimately of human decision, as psychologist / polymath Carl Jung noted in 1940 when first referencing the approach of the Aquarius equinox epoch. A Resolution by the IAU General Assembly updating the Aquarius-Pisces constellation boundary for greater precessional accuracy and human inclusivity could place the arrival of the Sun at the March equinox in constellation Aquarius in 2000 AD, to the great advancement for Astronomy, the IAU, and Humanity.

131.02 — When Will It Be...U.S. Naval Observatory Daylight Savings Time Calculator

Mark Thomas Stollberg[1]; Malynda Chizek-Frouard[1]; Cross Ziegler[2]; Teresa Wilson[1]; Jennifer L. Bartlett[1]

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"Spring forward, fall back" is a memory aid that everyone uses to switch their clocks onto and off of Daylight Saving Time (DST) each year. But who can remember when DST starts and ends? Why do we do this at all? The U.S. Naval Observatory (USNO) now has an on-line DST calculator (https://aa.usno.navy.mil/data/docs/daylight_time.php) and an updated information page (https://aa.usno.navy.mil/faq/docs/daylight_time.php) to answer those questions. The calculator uses The Uniform Time Act of 1966 and its subsequent revisions (1974, 1986, and 2005) to allow a user to find the beginning and ending dates for DST in the U.S. from 1967 to 9999; calculations for future years assume the current rules remain in effect. Users may also access this web calculator via an Application Programming Interface (API), which enables them to use the output in their own applications. Documentation for using all USNO API-enabled calculators, including sample calls, is also available online (https://aa.usno.navy.mil/data/docs/api.php).

131.03 — Clickers in the Classroom: Dramatic Results from an Accidental Experiment

Stephen J. Kortenkamp[1]; Byron Hempel[1]

[1] *University of Arizona (Tucson, Arizona, United States)*

Advocates for the use of clickers in university STEM classes can find support in studies comparing engagement and performance of students in similar courses taught by different instructors who either use or do not use clickers. However, distinguishing effects of clicker use from those due to different instructors can be challenging. Here we report results from an accidental experiment that arose due to an unforeseen leave of absence of an instructor just one week into a semester. The orphaned class was adopted by another instructor (SJK) who was already teaching a different section. Thus, the experimental setting involved the same instructor teaching two sections of an introductory planetary science course with the same lectures/activities. The fundamental difference? One class used clickers from the beginning of the semester while with the adopted class clickers were not a component of the original instructor's syllabus and so were not initially used. Both classes experienced identical questions/prompts and were given the same amount of time to consider and respond to the prompts. Students in the non-clicker class were encouraged to write responses in their notes and volunteers were solicited to verbally contribute responses. Students in the clicker class were required to respond and after each question saw histograms of the responses of their peers. The two classes continued in this way until the first exam, about 4-5 weeks into the semester. Results from the first exam showed the clicker-class averaging nearly 10 percentage points higher than the non-clicker class (75.45 vs. 65.66), a difference with statistical significance and strong effect (Z=4.31). For ethical reasons this result prompted the instructor to immediately introduce clickers into the non-clicker class. Two subsequent exams in each class showed no statistically significant differences in the class averages (77.56 vs. 77.50 and 79.56 vs. 77.90; Z=0.03 and Z=0.83 respectively). This dramatic turnaround in performance of the non-clicker class suggests that the students' physical act of responding to prompts with clickers, and seeing the responses of their peers, was responsible for the improvement.

131.04 — The Cold Case of SN1054. Was it the First Cover-up in the History of Astronomy?

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We investigate the possible causes for missing historical records of the Supernova SN1054 in Europe. First, we establish that the previously acclaimed "Arabic" records from Ibn Butlan originate from Europe. As one of the most prominent scientists of the time, he was in Constantinople at the time of the event and actively participating in the Church feud. Secondly, we reconstruct the European sky at the time and find that the new "star" (SN1054) was in the west while the planet Venus was on opposite sides of the sky (in the east) with the Sun sitting directly between two equally bright objects, as documented in East-Asian records. We find a striking similarity to this picture in specially minted coins printed in Byzantium during this period. On these coins of limited edition, we suggest that the Emperor's head at the time, Constantine IX, might represent the Sun with two "stars" on each side – Venus in the east and SN1054 in the west, perhaps representing the newly split Christian churches. We suggest the east star points to the "stable" and well-known planet Venus representing the Eastern Orthodox church and the other new (and expected to be short-lived) Western Catholic church is represented by the new and fading star. We examine 29 coins of this rare Constantine IX Class IV batch and found that their stars are gradually fading in size by ~35% (or 1.50±0.25 mm). This change in star size across the Class IV coin sample could reflect the real situation on the sky where a similar rate of change in SN1054 apparent magnitude is estimated (mv ~1.4 mag) over the last six months of Constantine IX rule at the time when these coins were minted. While knowledge and understanding of sky events (such as SN) were very poor in the mid XI century, we argue that the Great Schism played an essential role in turning aside the reporting of this very obvious event on the European sky. Finally, we propose that engravings on tombstones (stećci) from several necropolises in today's Bosnia and Herzegovina (far away from the Church's influence) represent another true European record of the SN1054 event.

131.05 — A Limited Habitable Zone for Complex Life

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The habitable zone (HZ) is commonly defined as the range of distances from a host star within which liquid water, a key requirement for life, may exist at a planet's surface. Substantially more CO_2 than present in Earth's modern atmosphere is required to maintain clement temperatures for most of the HZ, with several bars required at the outer edge. However, most complex aerobic life on Earth is limited by CO_2 concentrations of just fractions of a bar. At the same time, most exoplanets in the traditional HZ reside in proximity to M dwarfs, which are more numerous than Sun-like G dwarfs but are predicted to promote greater abundances of gases that can be toxic in the atmospheres of orbiting planets, such as carbon monoxide (CO). In this poster, we show that the HZ for complex aerobic life is likely limited relative to that for microbial life. We use 1-D radiative-convective climate and photochemical models to circumscribe a Habitable Zone for Complex Life (HZCL) based on known toxicity limits for a range of organisms as a proof of concept. We find that for CO_2 tolerances of 0.01, 0.1, and 1 bar, the HZCL is only 21%, 32%, and 50% as wide as the conventional HZ for a Sun-like star, and that CO concentrations may limit some complex life throughout the entire HZ of the coolest M dwarfs. These results cast new light on the likely distribution of complex life in the universe and have important ramifications for the search for exoplanet biosignatures and technosignatures. This research was supported by the NASA Astrobiology Institute Alternative Earths team under Cooperative Agreement Number NNA15BB03A and the NExSS Virtual Planetary Laboratory under grant number 80NSSC18K0829. A preprint of this work can be found at https://arxiv.org/abs/1902.04720.

200 — Laboratory Astrophysics Division Plenary Lecture: The Role of Dust in the Molecular Universe, Xander Tielens (Leiden University, The Netherlands)

200.01 — The Role of Dust in the Molecular Universe

Alexander Tielens[1,2]

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Astrobiology, the study of emergence of life and the its distribution in the Universe, addresses the most fundamental questions in science: "How does life begin ?" and "Are we alone ?" Over the last 20 years, we have discovered that planets are bountiful in the galaxy and that one in every five solar-type stars has a planet in the habitable zone. We have learned that extremophiles have spread to essential every niche – even the seemingly most inhospitable ones – on our planet. And we have learned that life started essentially as soon as conditions permitted, within some 200 million of the late heavy bombardment, or perhaps even earlier. This has resulted in a paradigm shift from "Life on Earth is unique" to the premise "life is widespread". As a result, searching for prebiotic molecules in space that may jump start life

on nascent planets has taken on a life by itself. In this talk, I will summarize this shift in our thinking and the global processes that may have influenced the first astrochemical steps in space. The focus in this talk will be on astrochemistry – the starting point of astrobiology – the chemical evolution that takes place in space where simple molecules are transformed into complex molecules and complex molecules are broken down to simple ones. This chemical dance of the elements produces a wide variety of organic compounds. I will review the processes that drive this chemical evolution in space, particularly in regions of star and planet formation. The focus will be on understanding the raw materials that are delivered to newly formed planets and their relationship to the building blocks from which prebiotic material was formed and biological systems evolve with an emphasis on the role of dust in this chemical evolution.

201 — Star Formation, ISM and Related Topics Poster Session

201.01 — Constraints on Large Scale Fluctuations in the Galactic Magnetic Field

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The Galactic magnetic field consists of a large-scale, ordered component and turbulent fluctuations with a range of spatial scales. Values for the outer scale and amplitude of the fluctuations are uncertain. We discuss a novel method for measuring or limiting fluctuations on size scales of order 30-50 parsecs. The method uses Faraday rotation measurements (rotation measure or RM) for lines of sight from background radio sources through HII regions. Costa and co-workers (ApJ 821,92,2016; 865,65,2018) report RMs on 20-30 lines of sight through (or close to) each of two HII regions, the Rosette Nebula and W4. In both cases, the RMs are dominated by the HII region, and are consistent with the sign of the large scale Galactic field in that direction. This demonstrates that the polarity of the magnetic field in a sphere with radius 15-20 parsecs centered on the HII region is the same as the large-scale field at that location. A model-dependent analysis of these results limits the amplitude of the in-plane magnetic fluctuations to 50 - 70 % of the mean field. Future extensions of the method will be discussed.

201.02 — Circumstellar Dust around Mira Variables and the Importance of Maser Emission

Lisa Shepard[1]; *Angela Speck*[1]
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Asymptotic Giant Branch (AGB) stars are major contributors of cosmic dust to the interstellar medium. Understanding the formation of cosmic dust ejected from these stars is essential to understanding the broader topics of evolution and composition of stellar and interstellar objects in our universe. We investigate the formation of circumstellar dust by studying the relationship between maser emission and dust spectral features for a sample of Mira variables. This project requires investigating the infrared spectra of a sizeable sample of stars for which maser emission has been quantified. Using high-resolution space-based spectroscopy data along with ancillary data from the published literature, we determine the nature of dust grains around these stars. This is achieved using two separate but complimentary methods. First, we match the positions and widths of observed spectral features with those seen in laboratory spectra. This is achieved by modeling the star as a blackbody, which is subtracted from the observed spectrum to leave a residual dust-only spectrum. Then we fit a continuum to the dust only spectra and divide to obtain the emission efficiency Q of the observed spectral features. These are then compared to laboratory spectra of potential astrominerals. The second method determines the composition of the dust shell star using radiative transfer modeling. The dust shell parameters that result from these analyses will then be compared to the parameters of maser emission to determine whether trends exist. Here we present the first results of modeling the dust composition.

201.03 — Investigation of Mid-infrared Dust Spectral Features of Oxygen-rich AGB Star

Brian Hybben[1]; *Angela Speck*[1]
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Understanding cosmic dust and its origins furthers understanding into the evolution of stellar objects in the universe. Asymptotic Giant Branch (ABG) stars, being major contributors to the interstellar dust through their mass ejections, offers an opportunity to study stellar evolution and the impact of dust on its environment. We have investigated the oxygen-rich Mira variable star R Cas via radiative transfer modeling and infrared spectroscopic observations, taken with the Infrared Space Observatory (ISO), and the Infrared Astronomical Satellite (IRAS). Using DUSTY, a 1-d radiative transfer code, we have created models of the cosmic ejector from this AGB star. Because radiative transfer modeling is inherently degenerate, we sought ways to constrain the model input variables. Using previously determined stellar parameters, such as mass-loss rate and expansion velocity for R Cas, we estimate the condensation temperatures for various potential astrominerals. Using the published photometric data to constrain the visible and near-infrared portions of the star's spectral energy distribution, we aimed to match the observed spectroscopic data and determine to composition and density of the dust surrounding R Cas. Here we present preliminary models of the dust composition and discuss the methodologies for constraining model parameters.

201.04 — The Milky Way Project: Probing Star Formation with a New Yellowball Catalog

Grace A. Wolf-Chase[1]; Charles R. Kerton[3]; Kathryn E. Devine[4]; Johanna Mori[4]; Leonardo Trujillo[4]; Sarah Schoultz[4]; Tharindu K. Jayasinghe[2]; Matthew S. Povich[5]

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The Milky Way Project (MWP; Simpson et al. 2012) is one of nearly 100 active research initiatives in Zooniverse (zooniverse.org), the world's largest online platform for citizen science. MWP participants serendipitously discovered features they dubbed "yellowballs" (YBs) while searching Spitzer images for infrared "bubbles," which are characteristic of HII regions. Working with a small sample of YBs for which distance estimates were available via association with catalogued Red MSX Source (Lumsden et al. 2013) survey objects, Kerton et al. (2015) argued that YBs are young, compact photo-dissociation regions associated with intermediate and massive star formation. The current YB catalog contains over 6,000 objects, and includes the GLIMPSE/MIPSGAL inner galactic plane legacy surveys (Benjamin et al. 2003; Churchwell et al. 2009; Carey et al. 2009), the Cygnus-X legacy survey (Beerer et al. 2010; Hora et al. 2007), and the Spitzer Mapping of the Outer Galaxy (SMOG; Carey et al. 2008) legacy survey. Here, we present results of a pilot study of 368 YBs in the 30-40-degree longitude range of the galactic plane. We extracted ^{13}CO spectra, obtained from the Boston University Five College Radio Astronomy Observatory Galactic Ring Survey (Jackson et al. 2006), toward YBs in order to determine molecular cloud velocities. Distances to these clouds were then computed using a Bayesian distance calculator that considers kinematic distance, displacement from the galactic plane, and proximity to individual parallax sources (Reid et al. 2016). Associations of YBs with dense clumps in the Hi-Gal catalogue (Elia et al. 2017) and 2D Gaussian modeling of the Spitzer 8- and 24-micron emission enabled us to determine critical physical properties of these objects. We find compelling evidence that YBs are compact star-forming regions spanning several orders of magnitude in luminosity and occupying a relatively short transitional phase, when stellar content is first revealed, but the surrounding ISM remains relatively undisturbed. Thus, YBs are critical targets for studies relating stellar content to the initial conditions for star formation.

201.05 — Analyzing the Velocity Structure of the Young Protostellar Disk and Collapsing Envelope Around Protostar L1527

Brandon Alexander Hilliard[1]; Susan Terebey[1,2]

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The life of a protostar begins in a giant molecular cloud of gas and dust, as a dense cloud core. After the dense core becomes self-gravitating it begins to collapse. If pressure and gravity are the dominant forces then angular momentum will be conserved. The collapse quickly leads to a morphology that includes a protostar, low-mass disk, infalling envelope, and outflow cavity. The advent of ALMA means that the velocity of the infalling gas is now measurable. In this study, the trajectories of collapsing material (infalling with rotation) toward the central mass will be visualized along line of sight velocities by implementing rotational kinematics and thereby used to model the structure for different protostar sources. Visualizing the motion of the material both in the midplane of the disk and outside this region will also be vital in creating a holistic model that can be compared with data from ALMA. The motion of the gas and dust, during the earliest stages of the protostar's evolution, will be fundamental in determining how the star system develops, and reveal key physical and chemical characteristics. This investigation will discuss how the velocity structure model can be improved, and demonstrate simulated protostar data

in relation to the well-known model of an edge-on source, namely the protostar L1527.

201.06 — Radial Velocity Monitoring of the Young Star Hubble 4

Adolfo Carvalho[1]; Christopher M. Johns-Krull[1]; Lisa A. Prato[2]
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We have been spectroscopically monitoring the young star Hubble 4 for approximately 10 years using the 2.7 m Harlan J. Smith telescope at McDonald Observatory. Our goal is to monitor this star's radial velocity (RV) variations, and we have collected over 65 observations of this 2-3 Myr old T Tauri star. In addition, we analyze archival imaging of Hubble 4 obtained with the ACS instrument aboard the Hubble Space Telescope to measure the flux ratio between the members of this binary system. The RV measurements of Hubble 4 clearly reveal the long period (~9 yr) variations due to the orbit of this binary (semi-major axis of 5.6 AU) as well as much shorter period (~1.5 d) variations due to stellar rotation. By fitting and removing the variations due to orbital motion, we also find lower bound of ~5 yr on the lifetime of star spots on the surface of the star. We discuss the implications of these findings for RV searches aimed at detecting planets around young stars.

201.07 — (withdrawn)

This abstract was withdrawn.

202 — Galaxies & Galaxy Evolution Poster Session

202.01 — A Search for Tidal Tails in the Satellite Galaxy Carina

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We searched for evidence of tidal stripping in the spatial structure of the dwarf satellite galaxy Carina using data from the European Space Agency satellite Gaia. The satellites of our Milky Way Galaxy are remnants of clues to its birth. Carina is intriguing because it has a more extended star formation history than other dwarf satellite galaxies of similar mass. In larger satellite galaxies the gas is retained longer, and this allows star formation to continue. The star formation history of Carina suggests that it was once more massive, and has been truncated by the gravitational forces of the Milky Way or some other satellite. Gaia data provides precise photometry, proper motions, parallaxes, and positions for over one billion stars. The proper motion and parallax data are especially intriguing, as measurements of such precision were not previously available for most of the stars. We selected potential members of Carina based on proper motion and position in the color-magnitude diagram over an area of the sky ~6.5 degrees across, and used these stars to search for low-surface-density indications of tidal interaction, such as non-axisymmetric distortions of the outer regions of Carina or extended tails along the direction of orbital motion that would indicate tidally-removed stars. This project has been supported by funding from National Science Foundation grant PHY-1560077.

202.02 — Analysis of the RR Lyrae variable population in DDO216

Eleanor Stuart[1]; Ata Sarajedini[1]; Jillian R. Neeley[1]
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RR Lyrae (RRL) variable stars are some of the oldest stars in the universe and are widely used to gain insight into the properties of their host populations. They are straightforward to locate due to their periodic variability and are used as a standard candle because their luminosities can be predicted from observable quantities such as the period. In this study, we identified and characterized RRL in the dwarf galaxy DDO216, using archival Hubble Space Telescope (HST) observations. We identified about 1200 RRL candidates and used software to fit light curve templates to the data before manually evaluating the fit of each one and selecting about 150 RRLs that fit the templates well. From there, we plotted a Bailey diagram and a color-magnitude diagram to examine their amplitudes, periods, temperatures, and luminosities. The preliminary Bailey diagrams follow the expected shape, with separate groups indicating ab-type and c-type RRLs, and the HR diagram shows RRLs in their predicted location on the horizontal branch. Individual metallicities for the RRL were calculated based on a period-metallicity relation, and we use a period-Wesenheit-metallicity relation to calculate the distance to DDO216. Once these properties of the RRLs have been analyzed, further research

into the composition and evolution of DDO216 can be conducted, which will allow us to better understand the evolution of dwarf galaxies.

202.03 — Searching for Intermediate Mass Black Holes in Spiral Galaxies Using Pitch Angles Gathered by Citizen Scientists

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We introduce *Spiral Graph*, a citizen science project dedicated to estimating the mass (M) of black holes (BHs) found in the nuclei of spiral galaxies. The main goal of this project is to identify intermediate mass black hole (IMBH; 10^2 $M_\odot$ < M_{BH} < 10^5 $M_\odot$) candidates in an initial, stellar-mass complete sample of 6222 spiral galaxies. To date, few confirmed IMBHs have been identified and the discovery of any new candidates may provide much needed clues to the evolutionary history of more common supermassive BHs (M_{BH} > 10^5 $M_\odot$) and their host galaxies.

Utilizing the Zooniverse platform, we developed a set of workflows for *Spiral Graph* that makes use of the M_{BH} – spiral arm pitch angle (PA) relationship to estimate central BH mass. Volunteers are tasked with fitting ellipses to the outer isophotes of galaxies so that they may be deprojected to a face-on view. They are asked if each galaxy in question is indeed a spiral galaxy allowing us to identify any subjects that may have been previously misclassified. Once the spiral galaxies are confirmed and deprojected, volunteers are then tasked with tracing over any visible arms. These tracings are input into an algorithm called P2DFFT that is used to measure the degree of winding of the arms (PA). Applying the M_{BH} – PA relationship will allow us to identify any IMBH candidates. These candidates are flagged for follow-up spectroscopic observations which will be used to independently confirm their mass via the M_{BH} – σ relationship.

202.04 — A Comparison of Supermassive Black Hole Mass of NGC 4151 Using Different Methods

Ismaeel Al-Baidhany[1]
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Abstract We present a new estimate of the black hole (BH) mass in the Seyfert 1 galaxy, NGC 4151. We selected a sample of nearly face-on spiral galaxy and used IRAF to determine the ellipticity and major-axis position angle in order to deproject the galaxy image to face-on. A two-dimensional Fast Fourier Transform was then applied to the deprojected image in order to measure the spiral arm pitch angle and, thereby, provide a SMBH mass estimate. We compared this preliminary result of the black hole (BH) mass in NGC 4151 galaxy with the BH mass has been estimated from seven independent techniques (stellar dynamics, gas dynamics, reverberation mapping , MBH-σ*, MBH-Vrot, MBH-n, MBH-Lbulge, and MBH-P relation). We found the mass values for the different techniques are in reasonable agreement with the recent estimate from stellar dynamics, gas dynamics, and reverberation mapping techniques. Key words: supermassive black hole–spiral galaxy- bulge luminosity – dispersion velocity-rotation velocity – pitch angle.

202.05 — Selection Bias and Error Analysis in the measured properties of Spiral Galaxies out to Redshifts of 2

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Recently, evidence has been presented for a strong correlation between the mass of central black holes and spiral arm pitch angles in local disk galaxies (Berrier et al., 2013). This implies an easier and more effective method for determining central black hole masses hosted in spiral galaxies at higher redshifts (greater distance) if the correlation can be shown to hold at these large distances. Measuring the spiral arm pitch angles may be more reliable than current methods as pitch angle techniques are dependent on imaging rather than spectra. Although, it is currently unknown if measurement techniques applied to local galaxies are also effective where the redshift is high and the resolution is lower. High redshift and low resolution obviously makes the determination of the spiral arm pitch angle, at least, more difficult and prone to errors. We propose to continue our investigation of the selection biases and errors inherent in applying local galaxy measurement techniques to high redshifted galaxies by working off of our previously made progress, and attempting to detect redshifted spiral galaxy simulations as spirals from survey data that they will be inserted into, measuring their spiral arm pitch angles, forming a selection bias matrix and measurement error matrix, and then analyzing them for results. Both the selection bias and measurement error matrix will be functions of pitch angle and other specified properties, and will be made publicly available for the purpose of easily accessing data, applying correlations, and being referenced for other research. One thing we will be able to use to our advantage when measuring spiral arm pitch angles is the relation predicted by density wave theory that the higher the concentration of central mass in a galaxy the tighter their spiral arms (pitch angle) will be, and the lower the concentration of central mass in a galaxy the looser their spiral arms will be.

202.06 — Enhanced X-ray emission from candidate Lyman continuum emitting galaxies

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The reionization of the early universe may have been helped by X-ray binaries. Feedback from X-ray binaries may clear paths of low column density out of galaxies, enabling the leakage of Lyman continuum radiation. However, the study of such distant galaxies is not feasible, so we instead turn to local analogs. We studied the X-ray properties of 8 potential Lyman leaking analog galaxies using Chandra observations. These galaxies were selected on the basis of weak emission lines and a predominately blue color. These criteria favor low column densities and imply the presence of young stars in the potential analogs. X-ray luminosities were found for point sources identified in the galaxies, as well as for the full extent of the galaxies. Three of the galaxies have X-ray luminosities well above theoretical calculations based on metallicity and star formation rate. These results support the concept that the presence of X-ray binaries may have been important to the process of reionization.

202.07 — A 100 kpc Ionized Gas Outflow Connecting a Compact Galaxy to its Circumgalactic Medium

David Rupke[1]; Alison L. Coil[2]; Gene Leung[2]; James Geach[4]; Christina A. Tremonti[3]; Ryan C. Hickox[7]; Amanda A. Kepley[8]; John Moustakas[6]; Paul Sell[5]; Aleksandar Diamond-Stanic[10]; Gregory Rudnick[9]

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The circumgalactic medium (CGM) of galaxies holds large, metal-enriched gas reservoirs. The origin of this gas remains elusive, but expulsion from galaxies through metal-enriched galactic winds plays a role. We present a detection of an enormous, 100 kpc ionized gas nebula in [OII] with the Keck Cosmic Web Imager (KCWI). It surrounds a compact star-forming galaxy at $z \sim 0.5$. The hourglass shape of the nebula, high-velocity ionized and molecular outflows, and young plus poststarburst stellar population are consistent with multiple gas ejection episodes over the past several hundred Myr. The nebula reaches well beyond the galaxy's stars and perhaps to a substantial fraction of the virial radius, thus connecting the galaxy to its CGM.

202.08 — High Resolution Three-Dimensional Hydrodynamic Relativistic Jet Simulations of Radio-Loud AGN

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Jets emanating from radio-loud active galactic nuclei exhibit varying morphologies, which are usually classified as either Fanaroff-Riley I (weaker sources dominated by jets that have destabilizied) or FR II (strong sources with jets that remain stable and terminate in hot spots). We use the Athena relativistic hydrodynamics code to model the propagation of such jets in three dimensions. The critical initial parameters are the jet velocity and ratio of jet density to that of the ambient medium, which determine the jet power and determine the type of radio galaxy that develops. We previously computed a suite of simulations with a wide array of these parameters at a reasonably high resolution and characterized the types of jets that developed. With additional computational power now available, we have now improved the resolution of many of these simulations by increasing the number of zones per jet radius from 10 to 20. For a selection of inlet jet velocities and densities we compare these higher resolution simulations to the previous runs to better analyze the distinguishing characteristics of these propagating jets, such as turbulence within the cocoon and shock structures within the jet column. These allow us to more confidently classify each jet and refine the boundary between the FR I and FR II classes.

202.09 — Toward a More Physical, Self-consistent Model of Narrow z(abs)∼z(em) Absorbers in Quasar Spectra

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It is well-accepted that quasars are powered by the accretion of matter onto supermassive black holes. The accretion process appears to yield a variety of structures including a disk, a hot corona, broad and narrow emission line regions, a jet, an obscuring torus, and a mass outflow. The mass outflow is often regarded as the origin of not only the optical and ultraviolet broad emission lines, but also provides a natural explanation for ultraviolet broad absorption lines. The case of narrow absorbers (Δv <500 km/s) appearing on top of the broad emission lines is still outstanding in terms of origin and structure. Part of the confusion is that narrow absorbers, commonly found with UV doublets from MgII, CIV, or OVI, arise from an eclectic variety of structures like interstellar, intergalactic, and intragalactic gas. Recently, we have begun using the NV λλ1238.821, 1242.804 doublet as these appear to preferentially select gas of an intrinsic origin. Here, we present a new approach to modelling NV absorbers from a more physical perspective than the standard modelling efforts (e.g., partial covering of a plane-parallel slab in front of a uniform background). Our goal is to have a utility that is less computationally expensive than a detailed hydrodynamic simulation. Our new model incorporates changes in the density of the absorbing structures (akin to inhomogeneous absorbers) and also gradients in the background continuum source (the accretion disk). For the disk, we currently employ a Novikov-Thorne solution for a geometrically thin disk around a spinning black hole. Hence, we parameterize the continuum using the black hole mass and spin, and the accretion rate. In addition, we anticipate adding a wind solution, and hot corona in order to reproduce the broad emission lines. From this, we can entertain the projected locations of the absorbers relative to the broad emission lines. The potential inclusion of a jet may also increase the applicability of this model to radio-loud quasars.

202.10 — Modelling Narrow NV z(abs)∼z(em) Absorbers in the HST/COS Spectra of Radio-selected Quasars

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From studies of high-resolution ultraviolet spectra (e.g., Misawa et al. 2007, Ganguly et al. 2013, Culliton et al. 2019a), it has become clear that absorption from the NV λλ1238.821, 1242.804 doublet yields purer samples of absorbers intrinsic to the quasar environment than their more common kin selected from CIV or OVI. A study of intrinsic NV absorbers with HST/COS spectra (Culliton et al. 2019b) revealed that NV absorbers observed in the spectra of radio-selected quasars occur in a variety of orientations as gauged by the radio core fraction, which is defined as the fraction of the radio emission arising from the radio core relative to the total (core plus lobes). Furthermore, the orientations in which NV absorption is observed do not appear to be segregated from the orientations where it is not observed. A segregation would be expected from an origin in a laminar flow. This is more consistent with the absorbers arising from a clumpy medium surrounding the quasar accretion disk. Here, we apply a model from our companion effort (Bakhsh et al., these proceedings) to examine further the inherent cloud structures that give rise to the observed kinematic absorption profiles. From our preliminary analysis, we are able to show that it is unlikely that the absorbing clouds are arranged in a spherically isotropic distribution as would be expected from an *in situ* origin at large distances from the central engine. Additionally, our modelling efforts may provide preliminary estimates of the ionization conditions, as well as locations of the absorbers relative to the emission line gas. From these, we hope to better disentangle how the clumpy NV-bearing gas is distributed relative to the central engine of the quasar.

202.11 — The Evolution of Intermediate-Velocity Clouds on a Collision Course with the Galactic Midplane

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Many intermediate-velocity clouds (IVCs) appear to be falling toward the Milky Way's disk, as evidenced by their negative line of sight velocities and their cometary morphologies. We have simulated IVCs in order to investigate the way in which they are transformed during their interactions with the interstellar medium. Here, we present our simulations of one such cloud, IVC 86-36. We compare our simulational results with the HI 21 cm emission observations made by Fukui et al. 2018, and we make predictions about the cloud's future behavior as it comes nearer to the galactic disk.

202.12 — Understanding the Relationship Between the Circumgalactic Medium and the Interstellar Medium

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The circumgalactic medium (CGM) is the region extending from the disk of the galaxy to the virial radius. As gas from the intergalactic medium (IGM) undergoes accretion, it has to flow through the CGM before it reaches the interstellar medium (ISM). The influence that the CGM has on the evolution of galaxies is still not fully understood. Previous studies on L* galaxies provide evidence that CGM gas accretion feeds the neutral gas content in the ISM. A similar study has not yet been conducted to show if these results hold for lower mass galaxies, which are much more abundant. We present the results of a dwarf galaxy survey investigating the connection between the neutral gas properties in the CGM and ISM. We use 21 cm emission to probe the ISM and explore its relationship to the CGM by comparing it to Lyman α (Lyα) absorption measurements obtained from the COS-Dwarfs program. We find that galaxies show a good Lyα covering fraction in the inner CGM. However, we find gaps in the neutral gas envelope in the outer CGM of these galaxies. We do not find a correlation between the strength of Lyα in the CGM and HI content in the ISM, which was seen for Milky Way-like galaxies. As a result, we believe that there are gaps in the CGM of dwarf galaxies due to loss of circumgalactic gas via feedback owing to the lower halo masses.

202.13 — Resolved observations of neutral hydrogen in nine z $\sim$ 0 luminous compact blue galaxies

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While bright, blue, compact galaxies are common at z $\sim$ 1, they are relatively rare in the local universe, and their evolutionary paths are uncertain. We have obtained resolved H I observations of nine z $\sim$ 0 luminous compact blue galaxies (LCBGs) using the Giant Metrewave Radio Telescope and Very Large Array in order to measure their kinematic and dynamical properties and better constrain their evolutionary possibilities. We find that the LCBGs in our sample are rotating galaxies that tend to have nearby companions, relatively high central velocity dispersions, and can have disturbed velocity fields. We compare our measurements to those previously made with single dishes and find that single-dish measurements tend to overestimate LCBGs' rotation velocities and H I masses. We also find that LCBGs are strongly rotationally supported at large radii, similar to other disk galaxies, though within their half-light radii the V_{rot}/σ values of their H I are comparable to stellar V_{rot}/σ values of dwarf elliptical galaxies. The disks of the LCBGs in our sample are gravitationally stable, though conditions may be conducive to local gravitational instabilities at the largest radii. Such instabilities could lead to the formation of star-forming gas clumps in the disk, resulting eventually in a small central bulge or bar.

202.14 — Tracing Young Stars in the Outer Disks of HI-rich Galaxy

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We present the first results from the UV-DISK program aimed to trace recent star formation (≤100 Myrs) in the outer low-density regions of 35 low-redshift galaxies. These galaxies are HI-rich with HI disks that extend to twice the optical size, and have been probed via COS-QSO absorption spectroscopy at impact parameter $\rho \leq 3R_{HI}$. We perform surface photometry on GALEX UV and PanSTARRs g, r, i observations for the sample, and combine it with VLA HI-21 cm maps to investigate the physics of star formation in the low-density outer disks of these galaxies. Here, we present the scaling relations between the spatial extent of young stars (≤100 Myrs) in the galaxy disk and the HI disk. In particular, we discuss the Extended-UV disk of NGC 3344 which we have also imaged in Hα. Combining HST COS-absorption spectroscopy, VLA HI-21 cm imaging, UV and Hα photometry allows us to correlate the formation of young stars to the local ISM conditions and CGM properties and map the full transport route of gas from the CGM to the star forming disk

203 — Cosmology and Related Topics Poster Session

203.01 — The Local Perspective on the Hubble Tension: Local Structure Does Not Impact Measurement of the Hubble Constant

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We use the largest sample to date of spectroscopic SN Ia distances and redshifts to look for evidence in the Hubble diagram of large scale outflows caused by local voids suggested to exist at z<0.15. Our sample combines data from the Pantheon sample with the Foundation survey and the most recent release of lightcurves from the Carnegie Supernova Project to create a sample of 1295 SNe over a redshift range of 0.01<z<2.26. We make use of an inhomogeneous and isotropic Lemaitre-Tolman-Bondi metric to model a void in the SN Ia distance-redshift relation. We conclude that the SN luminosity distance-redshift relation is inconsistent at the 4-5 σ confidence level with large local underdensities ($|\delta| > 20\%$, where the density contrast $\delta = \Delta\rho/\rho$) proposed in some galaxy count studies, and find no evidence of a change in the Hubble constant corresponding to a void with a sharp edge in the redshift range 0.023<z<0.15. With empirical precision of $\sigma_{H_0} = 0.60\%$, we conclude that the distance ladder measurement is not affected by local density contrasts, in agreement with cosmic variance of $\sigma_{H_0} = 0.42\%$ predicted from simulations of large-scale structure. Given that uncertainty in the distance ladder value is $\sigma_{H_0} = 2.2\%$, this does not affect the Hubble tension. We derive a 5 σ constraint on local density contrasts on scales larger than 69 megaparsec h^{-1} of $\delta < 27\%$. The presence of local structure does not appear to impede the possibility of measuring the Hubble constant to 1% precision.

203.02 — Towards cosmology from Lyman-α intensity mapping in HETDEX

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Future galaxy redshift surveys generally plan to observe emission lines from star-forming galaxies to measure the three-dimensional galaxy clustering. One ongoing example is the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX). HETDEX is designed to observe one million Lyman-α emitters (LAEs) over 1.9 < z < 3.5 in a unbiased way using the Integral Field Unit. However, such a unbiased nature of the HETDEX survey gives us an excellent opportunity. Namely, every 3D pixel in principle encodes the intensity of diffuse Lyman-α photons if exist. In this presentation, we discuss the feasibility of this so-called Lyman-α intensity mapping as a cosmological probe. We also introduce our simulation efforts in which the radiative transfer of Lyman-α photons are post processed in the Illustris simulation in order to have better understanding of the distribution of Lyman-α photons in the Universe.

203.03 — Galaxies in Place of Quasars: Discovery of a Low Redshift Damped Lyman-α system in the Spectrum of a Star Forming Galaxy

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With the next generation of large telescopes coming online in the following decade, a new method for discovering intervening gas clouds at high redshifts will soon become possible. This method consists of using spectra of star forming galaxies, in place of quasars (QSOs), to search for intervening clouds. Allowing for this method are new ground-based telescopes that will have the sensitivity needed to obtain high quality spectra of high redshift galaxies. By using this method, we will dramatically increase the number of sightlines probed which are currently limited by the number of QSOs. As a proof of concept, we present the discovery of a damped Lyman-α system (DLA) in the spectrum of a low redshift (z=0.175) star forming galaxy using data obtained from HST. This DLA is associated with the circumgalactic medium (CGM) of a foreground galaxy at z=0.17 probed at an impact parameter of 43 kpc. We detect H I at N(HI)=3×10^{20} cm^{-2}, along with multiple low-ionization transitions such as C II, Si II, and Si III in the spectrum of the DLA. This is a rare discovery as, to the level capable of current instruments, most QSO sightlines have been probed. With the improved sensitivity of new 30-meter class telescopes such as the Giant Magellan Telescope and the Extremely Large Telescope, it will be possible to probe intervening gas and CGMs at high redshifts using this method.

203.04 — Characterizing the Dark Matter Halos of Galaxy Groups and Their Hidden Baryonic Content

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A large fraction of galaxies today reside in groups and the dominant form of baryons in these groups is predicted to be a diffuse Intragroup medium (IGrM). Despite its importance, direct observational detection of the IGrM has been limited to the most massive groups where the IGrM is hot enough to emit soft X-rays. Therefore, we have mounted a controlled absorption-line experiment to search for the IGrM using a pre-defined sample of groups. The COS-IGrM survey is a medium-sized Hubble Space Telescope (HST) program to map the IGrM of 19 low-z ($0.08 < z < 0.17$) galaxy groups with the Cosmic Origins Spectrograph (COS). Using these data, Lyman α, O VI, and other absorption lines were measured to determine the column density of the intragroup gas. Collisional ionization equilibrium models were used to compare the observations with the predicted temperature dependent ionization fractions. We utilize individual galaxy spectra in an effort to characterize the O VI absorption as being due to the IGrM and not from the circumgalactic medium (CGM) of star forming galaxies (Tumlinson et al. 2011).

203.05 — Automated Physics-Based Detection and Identification of Intergalactic Clouds using Probabilistic Programming

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Absorption lines in the spectra of distant Quasi-stellar objects are our main source of information about physical conditions and composition of matter in the intergalactic medium. However, manual analysis of such spectra is time-consuming and error-prone, in part due to the unknown redshifts of absorption lines and the unknown number of intervening clouds. Automatic analysis has also been challenging for this problem: observational uncertainties make it difficult to use combinatorial search techniques, and approaches based on probabilistic inference typically require prior knowledge of the number of clouds. We present a new approach that supports a variety of QSO spectra studies while accounting for observational uncertainties as well as the unknown numbers and types of intervening clouds. We use a probabilistic programming language, Bayesian Logic (BLOG), that extends first-order logic semantics with probability theory and allows efficient specifications for physics-based probabilistic models. We show how our system would utilize the equivalent width and position of absorption lines in the spectra as observations. It also provides a rich query language for investigating properties of the possible intervening clouds. Answers to the resulting queries would be consistent with (and supported by) the input physics models. We will evaluate this representational approach using techniques for approximate probabilistic inference on the Hubble Space Telescope (HST) COS data that cover a range of background QSO up to Z = 1. The flexibility and robustness of this analytical approach would be invaluable in evaluating scientific hypotheses with large datasets such as those from HST as well as with data expected from forthcoming large observatories such as GMT, ELT, and TMT.

203.06 — Cosmic Voids as Laboratories for Neutrino Physics

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Massive neutrinos uniquely affect cosmic voids. We explore their impact on void clustering using both the DEMNUni and MassiveNuS simulations. For voids, neutrino effects depend on the tracers. As neutrino mass increases, the number of small voids traced by cold dark matter particles increases and the number of large voids decreases. Surprisingly, when massive halos are used as tracers, we see the opposite effect. How neutrinos impact the scale at which voids cluster and the void correlation is similarly sensitive to the tracers. This scale dependent bias is not due to simulation volume or halo density. We also present new results on scaling relations between tracers and voids as well as the impact of neutrino mass on void bias. The interplay of these signatures in the void abundance, clustering, and bias leaves a distinct fingerprint that could be detected with upcoming observations and help break degeneracies between different cosmological parameters. This work paves the way to exploit cosmic voids in DESI, PFS, Euclid, and WFIRST to constrain the mass of neutrinos.

203.07 — First Principles of Linger-Thermo Theory, a Time-Complementary Duality in Physics, Inherently Lead to Average Mass of Star Particles and Organism Cells

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Linger-thermo theory (LTT) is part of a time-complementary past-uncertainty/future-certainty spacetime duality in physics with uncertainty initial state that yields maximally efficient and affordable solutions such as in radar (Feria, 2014 SPIE Newsroom article 10.1117/2.1201407.005429 & 2018 US Patent 10,101,445). LTT has been used in astrobiology (Feria, AAS 49 PS) and dark-matter studies via thermotes (Feria, AAS 230). Thermotes surfaced in LTT in 2014 from the derivation of the entropy of flexible-phase mediums for use in lifespan studies. They simplify entropy finding and their energy is e_{Th}=$N_{DoF}k_BT/2$ where k_B is the Boltzmann constant, T is the temperature of the medium and N_{DoF} is the number of degrees of freedom (DoF) for a particle, e.g., 3 for photon-gas (PG) photons and 2 for black-hole (BH) particles in its event horizon. For the BH and PG their entropy is $k_B/2$ times the ratio of their mass-energy over the thermote energy, which then via the 2nd law of thermodynamics leads to the LTT conjecture that T decreases with time with the thermote energy loss fueling the Universe's expansion. Moreover, the eV mass of the BH and PG thermotes at the cosmic microwave background (CMB) temperature of 2.725 Kelvin is found to be 235.14 μeV and 352.71 μeV, respectively, values which fall within the 50 to 1,500 μeV range for the axion, a top dark matter candidate (Borsanyi, et al. 2016, Nature). In LTT the shape of the medium of mass M and volume V is modeled as a sphere of radius r where at its center its point-mass resides. In this LTT model there are M/m_G gyrador particles whose total kinetic energy matches the gravitational potential energy $GM^2/2r$ of the medium. Each gyrador of mass m_G orbits a quantum of operation (QoO) mass δM at the center of a sphere of radius δr with orbiting-speed v=$(G\delta M/\delta r)^{1/2}$ and $\delta M/\delta r$=M/r. In LTT the kinetic energy $m_Gv^2/2$ of the gyrador is set equal to the thermote energy e_{Th} which then yields m_G=$2re_{Th}/GM$ whose evaluation for the sun and humans matches the average mass of sun particles and human cells.

203.08 — ΛCDM or self-interacting neutrinos? - how CMB data can tell the two models apart

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Of the many proposed extensions to the LambdaCDM paradigm, a model in which neutrinos self-interact until close to the epoch of matter-radiation equality has been shown to provide a good fit to current cosmic microwave background (CMB) data, while at the same time alleviating tensions with late-time measurements of the expansion rate and matter fluctuation amplitude. Interestingly, CMB fits to this model either pick out a specific large value of the

neutrino interaction strength, or are consistent with the extremely weak neutrino interaction found in LambdaCDM, resulting in a bimodal posterior distribution for the neutrino self-interacting cross section. In this paper, we explore why current cosmological data select this particular large neutrino self-interaction strength, and by consequence, disfavor intermediate values of the self-interaction cross section. We show how it is the l ≥1000 cosmic microwave background temperature anisotropies, most recently measured by the Planck satellite, that produce this bimodality. We also establish that smaller scale temperature data, and improved polarization data measuring the temperature-polarization cross-correlation, will best constrain the neutrino self-interaction strength. We forecast that the upcoming Simons Observatory should be capable of distinguishing between the models.

204 — Solar Physics Division (SPD), Poster Session II

204.01 — DKIST User Tools for Level 1 Data

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The DKIST user tools aim to lower the barrier of entry to scientific discovery with the DKIST level one data. The tools provide standard python interfaces to the data and coordinate information in a way that enables interoperability with the wider Python ecosystem. The user tools are based on widely used Python packages such as Dask and matplotlib as well as the SunPy and Astropy packages. The DKIST user tools will provide Python interfaces for:

Searching the DKIST Data Centre, retrieving metadata about datasets in ASDF format and downloading whole datasets or subsets as collections of FITS files. Maintaining a record of retrieved datasets and their locations. Loading data from large numbers of FITS files efficiently and transparently Performing high-level operations on the data and coordinate information in tandem.

This poster will provide demonstrations of implemented and future functionality and discuss the integration with analysis and visualization libraries.

204.02 — The DKIST Data Center - Curating, Calibrating and Distributing DKIST Data

Alisdair R. Davey[1]
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The challenges of dealing with the upcoming data from the the Daniel K. Inoue Solar Telescope (DKIST) are diverse. DKIST will easily dwarf even the data volumes created by SDO, but when you add in the longevity of the observatory (two full solar cycles), the complexity of the 5 instrument packages on the Coude platform, the desire to create an automated calibration pipeline, designed to remove the instrument effects of a ground based teelscope for all observation sets, and the need to be able to distribute the large datasets in an effecient, reliable manner, then the true scale of the tasks become obvious. Here I discuss how we meet all these challenges, leveraging not only best in breed open source source software, but also engineering design, building and testing principles, to create a next generation solar physics data center capable of meeting the challenges DKIST presents.

204.03 — Localized Quasi-Periodic Fluctuations in C II, Si IV, and Fe XXI Emission During Chromospheric Evaporation in a Flare Ribbon Observed by IRIS and RHESSI on 2017 September 9

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We investigate the onset of a GOES M3.7 flare on 2017 September 9 with rapid cadence (9.4 s) ultraviolet stare spectra obtained with IRIS in five 1-arcsec slit segments. Our analysis is based primarily on integrated intensities and Doppler velocities of C II at 1334.5 Angstroms (T ~ 0.025 MK), Si IV 1402.7 (0.079 MK), and Fe XXI 1354.1 (11 MK). The four segments within the ribbon show systematically earlier starting times for the low-T lines (C II and Si IV) than Fe XXI; further, the velocities derived for Fe XXI are generally directed upward along the line of sight. This is consistent with the standard flare model, in which beams of nonthermal particles ionize and heat the chromosphere, and drive chromospheric evaporation: as the temperature and ionization stages of the chromospheric plasma increase, intensities of emission lines also increase, first from lines in lower stages of ionization, and later from lines in higher stages of ionization. Where quasi-periodic fluctuations were observed in the ribbon in both low-T and Fe XXI emission, the peaks in the low-T light curves preceded those in the Fe XXI light curve, and peaks in the Fe XXI upward velocity typically also preceded those in the Fe XXI light curve. Thus the behavior of each individual fluctuation was similar to that of a standard flare, suggesting that each individual fluctuation was due to a separate injection of nonthermal particles into the chromosphere. Based on RHESSI HXR observations, we estimate sufficient beam energy flux to drive explosive chromospheric evaporation.

204.04 — Hard X-ray Spectroscopy of Six NuSTAR Microflares

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Hard X-ray (HXR) emission in solar flares can originate from regions of high temperature plasma, as well as from non-thermal particle populations. Both of these sources of HXR radiation make solar observation in this band important for study of flare energetics. NuSTAR is the first HXR telescope with direct focusing optics, giving it a dramatic increase in sensitivity over previous indirect imaging methods. Here we present NuSTAR observation of six microflares from one solar active region during a period of several hours on May 29th, 2018. Spectral fitting of emission at each flare time shows excess high energy emission over an isothermal spectral component in all six flares. The most likely origin of this excess could be either additional volumes of high-temperature plasma, or non-thermally accelerated particles. For each event, characterization of this excess is presented, including determination of upper limits on the non-thermal emission possible in events where it is not directly observed.

204.05 — The Eruption of Outer Spine-like Loops Leading to a Double-Stage Circular-Ribbon Flare

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Studying circular-ribbon flares (CRFs) and the related magnetic structure/topology can advance our knowledge of solar eruptions in general. Although they are usually confined events, CRFs can also be associated with coronal mass ejections (CMEs) when a filament embedded under the fan dome erupts. Here we study the M8.7 CRF occurred in NOAA AR 12242 (SOL2014-12-17T04:51), which is accompanied by a CME but the active region filaments remain intact. Using coronal magnetic field reconstructed under the nonlinear force-free field assumption, we find that the outer spine-like loops form a twisted magnetic flux rope (MFR1) rooted at the edge of the fan-dome field with opposite twist, and that there is a second flux rope (MFR2) lying above the main polarity inversion line (PIL). We divide the event evolution into two main stages based on EUV observations. (1) The event onset is featured with small bidirectional jetting activities between the sheared filament field and MFR1, immediately followed by an upward motion of MFR1. During this first stage, the inner/outer and the circular ribbons begin to brighten up. (2) After about 10 minutes, another ejection stems from the main PIL region. This is most probably related to an eruption of MFR2, as the twist of MFR2 footpoints exhibits a clear decrease subsequently. In this second stage, all ribbons are significantly enhanced. We discuss these results in favor of a scenario where the initial reconnection between the sheared filament field and MFR1 triggers the latter to erupt, then the erupting MFR1 interacts with the overlying fan-like field to allow a second eruption of MFR2. This event thus represents a new type of eruptive CRFs caused by an unstable outer spine-like loops without involving a filament.

204.06 — Analyzing deviations from optically thin emission in flare ribbon plasma using IRIS observations of Si IV resonance lines

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It is well-established that the Si IV resonance line pair at 1394 and 1403 Å observed by the Interface Region Imaging Spectrograph (IRIS) exhibits a 2:1 intensity ratio in optically thin plasma. Deviations from this ratio may arise from optical thickness (Mathioudakis et al. 1999) and/or geometric effects (Kerr et al. 2005) in the emitting plasma. These effects are expected to be particularly prevalent in the dense chromospheric plasma that forms the ribbons during a flare, and the Si IV resonance line ratio therefore provides a diagnostic of the plasma conditions at the flare loop footpoints. Recently, Kerr et al. (2019) used RADYN simulations to demonstrate that a significant fraction of the Si IV flare ribbon emission may form at cooler temperatures, even for relatively small flares. Their

results showed changes to both line shape and intensity in flare plasma, and they recommended caution when interpreting Si IV emission in flare ribbons. Additionally, they noted that only a handful of studies using IRIS observations have reported the line ratio in flares. In this work, we report on our work to create a catalog of the line ratio for additional flare ribbon events in the IRIS observation database. We select IRIS observations of flares that record both Si IV resonance lines with an 8-step or fewer raster, and identify 28 candidate observations for which the flare ribbon is covered by the spectrograph slit. We establish criteria for identifying spectra that capture flare ribbon emission and for eliminating spectra that contain defects (e.g. saturated pixels). We calculate line intensities (less background contribution) and construct the line ratio for all selected spectra in each observation, and report the mean, median, and deviation of the line ratio for each flare ribbon. Based on our results, we briefly discuss physical implications for interpreting Si IV emission in flare ribbons.

204.07 — Multi-instrument Comparative Study of Temperature, Number Density and Emission Measure during the Precursor Phase of a Solar Flare

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The precursor brightenings of solar flares hold valuable clues concerning the flare triggering and energy release mechanisms, but have not been well studied. This paper presents a multi-instrument study of the two precursor brightenings prior to the M6.5 flare (SOL2015-06-22T18:23) in NOAA active region 12371, with a focus on the temperature (T), number density (n) and emission measure (EM) of these two precursors. The multi-instrument data used in this study were obtained from four instruments with variety of wavelengths, i.e., the Solar Dynamics Observatory's Atmospheric Imaging Assembly (AIA) in six EUV passbands, the Expanded Owens Valley Solar Array (EOVSA) in microwave, RHESSI in hard X-ray and GOES in soft X-ray. We compare the temporal variation of T, n and EM derived from different data sets during the precursor period and discuss the differences in terms of the sensitivity of the instruments.

204.08 — Statistical Study of Solar Flares Observed in Lyman-α Emission During Solar Cycle 24 Using GOES-15

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The chromospheric Lyman-α line of hydrogen (Lya; 1216A) is the strongest emission line in the solar spectrum. Fluctuations in Lya are known to drive changes in the D-layer of Earth's ionosphere (>70km), and recent studies suggest that during solar flares, up to 10% of the energy deposited in the chromosphere by nonthermal electrons is radiated away by the Lya line alone. Despite the energetic importance of Lya there have been relatively few studies in the literature that focus on the behaviour of Lya emission during flares. This work presents a statistical study of almost 500 M- and X-class flares observed in Lya emission by the EUVS instrument on GOES-15 during Solar Cycle 24. It was found that up to 100 times more energy can be radiated by Lya compared to soft X-rays (also a driver of D-layer fluctuations); that Lya enhancements during flares are comparable to or greater than those measured due to solar rotation variability, albeit on much shorter timescales; and that center-to-limb variations appear to be negligible despite Lya being optically thick.

204.09 — Modeling of Electron Acceleration and Transport along Realistic Magnetic Loops

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We provide an explanation on the origin of the observed solar hard X rays during the 1 September 2014 solar eruptive event. The CME-driven coronal shock is magnetically connected to the visible disk, suggesting the coronal shock may be the strongest candidate as the particle accelerator. A 3D triangulation technique, based on remote-sensing observations is used to model the expansion of the CME shock. Realistic time-dependent evolution of shock properties along field lines and realistic background

fields for particle transport from the shock to the solar surface are obtained. We develop Shock-Drift Acceleration and Diffusive-Shock Acceleration models with multiple interactions due to particles bouncing along magnetic loops. We look into the effect of mirror force on transport process. The returning of the downstream electrons to the upstream is also considered. We verify that electrons can be accelerated to a few MeV and reach the chromosphere producing hard X-rays.

We also study the type II radio bursts during this event and provide an interpretation for the observational characteristics.

204.10 — A Database of Flare Ribbon Properties From Solar Dynamics Observatory

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We analyze a database of >3000 of solar flare ribbon events corresponding to every flare of GOES class C1.0 and greater within 45 degrees from the disk center, from April 2010 until April 2019, observed by the Solar Dynamics Observatory (SDO). For every event in the database, we compare GOES X-ray flare properties with corresponding active-region and flare-ribbon properties. We present the results and discuss other flare quantities one could derive from the SDO to deepen our understanding of solar flare physics.

204.11 — On the observation of a classical loop-prominence system during the 2017 September 10 flare.

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We report observations of white-light ejecta in the low corona after the 2017 September 10 flare, using data from the Helioseismic and Magnetic Imager (HMI) of the Solar Dynamics Observatory. We report the observation of a classical loop-prominence system, but are brighter than expected and possibly seen here in the continuum rather than line emission. We studied the spatial and temporal relation between RHESSI X-ray and the white-light emissions. We also studied the HMI spectroscopic data to determine the most probable emission mechanism that can explain the observation of the loop-prominence system.

204.12 — *FOXSI-2* Solar Microflares: Hard X-ray Spectroscopy and Flare Energetics

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Sensitive measurements of solar flares in the hard X-ray regime are necessary for investigating energy release and transfer during flaring events, as hard X-rays provide insight into the acceleration of electrons and emission of high-temperature plasmas. Due to use of indirect imaging, past solar-dedicated instruments in this energy range have been fundamentally limited in sensitivity and dynamic range. By instead using a direct imaging technique, the structure and evolution of even small flares and active regions can be investigated in greater depth. The *Focusing Optics X-ray Solar Imager* (*FOXSI*), a hard X-ray instrument flown on three sounding rocket campaigns, seeks to achieve these improved capabilities by using focusing optics for solar observations in the 4-20 keV range. During the second flight, which occurred on 2014 December 11, *FOXSI-2* observed two microflares, estimated as *GOES* class A0.1 and A0.3. Here we present imaging and spectral analyses of these microflares, investigating the nature of energy release and exploring the structure and dynamics in comparison to larger flares. Through this work, we find evidence for high-temperature plasma (~10 MK) as well as spatial and temporal complexity for microflares that are an order of magnitude fainter than those observed by previous solar-dedicated instruments in this energy range, highlighting the benefits of direct imaging.

204.13 — Mg II NUV Spectra in Solar Flares: Modelling approaches and Velocity Diagnostics

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The Interface Region Imaging Spectrograph (IRIS) has observed the Mg II NUV spectrum (the h & k resonance and the subordinate triplet), in hundreds

of solar flares. These lines form throughout the chromosphere, offering excellent diagnostic potential and a window into the location of flare energy deposition. A number of studies have attempted to forward model both the general properties of these lines in flares, and specific flare observations. Generally, these investigations have post-processed snapshots of solar atmospheres from hydrodynamic or radiation hydrodynamic flare simulations through advanced radiation transport codes. There has, however, not been a survey of how the physics included in these radiation transport codes affects the solution. We present here a detailed study showing what physics must be included when forward modelling these lines, including the use of partial redistribution (PRD), the specific treatment of (PRD), the need for a sufficiently large model atom, the inclusion of Mg I in NLTE, the inclusion of other species in NLTE, and the impact of using non-equilibrium hydrogen populations. Futher, we contrast Mg II computed in statistical equilibrium with a computation that includes non-equilibrium effects. Finally, we apply commonly used observational metrics for inferring Doppler speeds to the synthetic spectra, demonstrating that optical depth and radiation transfer effects can confuse the interpretation of those measurements.

205 — Laboratory Astrophysics Division (LAD), Poster Session

205.01 — Laboratory Calibrations of Fe XII-XIV Line-Intensity Ratios for Electron Density Diagnostics

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We have used an electron beam ion trap to measure electron-density-diagnostic line-intensity ratios for extreme ultraviolet lines from Fe XII, XIII, and XIV at wavelengths of 185-205 and 255-276 Angstrom. These ratios can be used as density diagnostics for astrophysical spectra and are especially relevant to solar physics. We have compared our results to atomic calculations using the Flexible Atomic Code and identified some lines that are reliable and others where there are discrepancies between experiments and theory.

205.02 — Status & Needs of Astrophysical Plasma Models

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X-ray emission from energetic astrophysical plasmas is typically analyzed using a range of software packages, including SPEX and XSPEC. Within these packages are several different models for different types of astrophysical plasmas. The most complex involve detailed modeling of spectral line emission from thermal or photoionized plasma, based on the SPEX, AtomDB or XSTAR plasma codes. These plasma codes combine atomic data with models of electron, photon or proton collision dominated plasmas to produce a complete spectrum for a range of plasma conditions, including temperature, density, elemental composition and more. While it could be expected that these plasmas produce identical results for the same input plasma conditions, there are several reasons why they do not, relating to different input atomic data, model assumptions and model intentions. I will discuss the different plasma models, their applications, underlying assumptions, and the similarities and differences in their results, as well as future needs for missions such as XRISM and Athena

205.03 — Relativistic Atomic Structure of the Au II Isoelectronic Sequence: opacity data for kilonova ejecta

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On August 17, 2017, the Laser Interferometer Gravitational Wave Observatory (LIGO) and VIRGO detected gravitational waves (GW170817) propagating from a binary neutron star merger, in which ejected material from the merger emitted thermal radiation in the optical and near-infrared (NIR). The ejecta is classified into two classes based on the atomic weight of the chemical composition: the first class is composed primarily of light (atomic mass number < 140), and the second class is composed of heavy elements (atomic mass number > 140). The latter incites the possibility that highly-dense mergers are the creation sites for heavier elements, as they are created by the heating of heavily radioactive nuclei, known as the rapid neutron capture mechanism (r-process heating). The observed thermal glow, known as a kilonova, can be attributed to the radioactive decay of heavy elements (Rb to U). Unfortunately, there is a limited amount of available spectroscopic data for these elements. The purpose of this research is to alleviate this problem by using the GRASP0[1] and GRASP2K[2], multi-configuration program packages which solve the Dirac-relativistic equation, to calculate atomic energy levels and transition probabilities of the Platinum (Pt) isoelectronic sequence (Pt I, Au II, Hg III, Tl IV). These findings are compared against available theoretical and experimental data[3]. The Au II results are used to simulate emission spectrum to interpret the Compact Toroidal Hybrid experiment with a gold-plated probe. This work was partially supported by NSF grant 1816984.

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205.04 — Laboratory Astrophysics at NASA Ames: Recent Results and Advances

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The Cosmic Simulation Chamber (COSmIC) facility was developed at NASA Ames to study, in the laboratory, neutral and ionized molecules and nanoparticles under the low temperature and high vacuum conditions representative of interstellar, circumstellar and planetary environments [1]. COSmIC is composed of a Pulsed Discharge Nozzle expansion that generates a plasma in a free supersonic jet expansion coupled to high-sensitivity, complementary in situ diagnostic tools, used for the detection and characterization of the species present in the expansion: a Cavity Ring Down Spectroscopy (CRDS) and fluorescence spectroscopy systems operating in the UV-Visible range [2], and a Reflectron Time-Of-Flight Mass Spectrometer (ReTOF-MS) [3]. We will present recent advances that were achieved in laboratory astrophysics using COSmIC. These include advances in the domain of the diffuse interstellar bands (DIBs) [4, 5] and in the formation of dust grains and aerosols from their gas-phase molecular precursors in environments as varied as circumstellar outflows [6] and planetary atmospheres [7, 8, 9]. An extension of the spectral response of the facility into the infrared (IR) range is in progress with the addition of a high-resolution near-IR to mid-IR CRDS system that will allow to further investigate cosmic molecules and grains with COSmIC. Acquisition of laser induced fluorescence spectra of cosmic molecule analogs and the laser induced incandescence spectra of cosmic grain analogs are also planned. Preliminary results in these fronts will presented and the implications of the on-going studies for astronomy will be addressed.

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205.05 — Rovibrational excitational of diatomic molecules due to H_2 collisions: Waiting for Webb

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The expected launch of JWST in 2021 will herald a new era in astronomy due to its unprecendented wavelength resolution and sensitivity in the near infrared (NIR). In particular, the NIR Spectrograph (NIRSpec, 0.6-5.3 microns) and the Mid Infrared Instrument (MIRI, 4.9-28.8 microns) will be able to access a wide range of molecular vibrational bands which have been heretofore difficult to observe from the ground. In preparation for modeling JWST observations of low-density and/or highly irradiated environments which are out of equilibrium, we have performed a series of full-dimensional scattering calculations to predict collisional rate coefficients for rovibrational excitation of H_2, CO, CN, SiO, CS, and SO due to the dominant collider H_2. In many cases, excitations as high as v=5 and/or J=40 have been obtained for temperatures as high as 3000 K. The impact of the new rate coefficients are illustrated with NLTE models of typical photodissociation regions, AGB outflows, and surface layers of protoplanetary disks.

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205.08 — Radiation cooling in laboratory photoionized plasmas

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In separate experiments performed at the Z facility of Sandia National Laboratories two different samples were employed to produce and characterize photoionized plasmas. One was a gas cell filled with neon, and the other was a thin silicon/oxygen slab tamped with plastic. Both samples were driven by the broadband x-ray flux produced at the collapse of a wire array z-pinch implosion. Transmission spectroscopy of a narrowband portion of the x-ray flux was used to diagnose the charge state distribution, and the electron temperature was extracted from a Li-like ion level population ratio. We discuss modeling and results of non-equilibrium atomic physics, the effect of the x-ray flux on the atomic level population kinetics, and their impact on the radiation cooling of laboratory photoionized plasmas. This work was sponsored in part by DOE NNSA Grant DE-NA0003875, DOE OFES Grant DE-SC0014451, the Z Facility Fundamental Science Program, and the Wootton Center for Astrophysical Plasma Properties.

205.09 — Radiation temperature characterization of a long duration x-ray source for a laboratory photoionized plasma experiment at OMEGA EP

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Long duration, i.e. tens of ns, broadband x-ray sources are important for laboratory photoionized plasma experiments relevant to astrophysics. In a series of experiments performed at the OMEGA EP laser facility, we have used the Gatling-Gun source to produce an x-ray drive that lasts for 30ns with a radiation temperature T_r =90eV. The Gatling-Gun source is comprised of three Cu hohlraums; each is filled with TPX foam and driven by a 10ns- square pulsed laser beam with 4.4kJ of UV laser energy[1]. The total source duration of 30ns is achieved by driving the three hohlraums sequentially in time, i.e. back-to-back. The radiation temperature was monitored with a VISAR diagnostic to check performance and compare with previous miniDMAX data[1]. We present measurements of the radiation temperature obtained from VISAR data from two series of experiments performed at OMEGA EP, in conjunction with radiation-hydrodynamics simulations of the VISAR package.

[1]D. Martinez, 2017 Annual OLUG Workshop.

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206 — iPoster Session: Solar Physics Division (SPD), Session II

206.01 — Investigating Reconnection Evolution using Si IV Doppler Velocity Measurments

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Spectroscopic measurements of flare ribbons can provide information about the magnetic reconnection process driving the flare. Part of the response of chromospheric material to the energy input from magnetic reconnection, is a redshift known as chromospheric condensation. The evolution of this redshift is related to how long the energy was deposited for, and the spatial scale of where the energy was deposited in the corona. In this study, we use Interface Region Imaging Spectrograph (IRIS) FUV observations of a flare on October 25, 2014 to measure Doppler shifts of the Si IV 1402 and 1393 Å lines and the time evolution of each line. Both Si IV lines are well fit using a sum of two Gaussian components. Here, we have developed a fitting procedure which will directly infer the Doppler velocity of the red and blue shifted component at each non-saturated ribbon pixel. We see that these red and blue shifted components peak to a maximum velocity and then decay away to its normal velocity. This is the behavior predicted by models of chromospheric condensation (Fisher et al. 1985, Longcope 2014). Using results from this study, we seek evidence for the reconnection length scale and the reconnection spatial dependence. This work is supported by a grant from NSF/AST.

206.02 — Statistical analysis of evolving flare parameters inferred from spatially-resolved microwave spectra observed with the Expanded Owens Valley Solar Array

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The newly completed Expanded Owens Valley Solar Array (EOVSA) performed microwave (MW) imaging spectroscopy observations during several flares that occurred during the first half of September 2017. The unprecedented high frequency and spatial resolution of these observations allowed us for the first time to infer, with 2-arcsecond spatial resolution and 1-second temporal cadence, the spatial distribution and evolution of the coronal magnetic field strength, the number density of the accelerated electrons, the power-law index of their energy distribution, as well as other associated flare parameters. Our methodology, which consists of independently fitting the MW spectra corresponding to each individual pixel of the evolving mult-frequency maps with uniform gyrosynchrotron source models, generated a statistically significant collection of evolving flare parameters whose generally smooth spatial and time variation demonstrates a collective behavior of the neighboring volume elements, and thus validates our approach. Here we report on the statistical properties of these physical flare parameters, their spatial distributions, and their temporal trends for significant portions of the duration of each flare, and we interpret our results in the context of the standard solar flare model involving magnetic energy release, magnetic reconnection, and particle acceleration.

206.03 — High Resolution Post-flare Loop Observations by GST and IRIS

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We present the study of post-flare loops, during the gradual phase of the 2015-06-22 M6.5 two-ribbon flare, which was observed by Goode Solar Telescope (GST) and Interface Region Imaging Spectrograph (IRIS). Imaging spectroscopic data in UV and Hα lines are analyzed, with supplementary data of magnetograms and EUV images. We compare the Doppler signals derived from Mg II 2791.59 Å, Si IV 1402.77 Å with those derived from Hα line to study the mass motions in the transition region and chromosphere. In addition, Hα images are used for tracing the structure and mass motion in loops. Furthermore, we investigate the oscillations of flare loops in Fe XXI 1354.08 Å and Hα lines. Finally, we compare our diagnostics with the results of flare loop modeling.

207 — iPoster Session: Stars & Friends I

207.01 — Intel Secure Key-Powered Radio-flaring Ultracool Dwarf Population Synthesis

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Over a dozen ultracool dwarfs (UCDs), which inhabit the boundary between low mass stars and brown dwarfs, are known sources of radio activity. This activity consists of highly (~100%) circularly polarized, high brightness temperature radio flares thought to be caused by the electron cyclotron maser operating in kG magnetic fields. Using the statistical properties of the population of UCDs know thus far together with well-characterized instrumentation at Arecibo Observatory, a Monte Carlo simulator may be constructed to gain insight into this intriguing class of objects. This simulator is powered by Intel Secure Key, also known as the RdRand instruction set, which is a new processor technology that uses a local entropy source to improve random number generation that has heretofore been used to improve

cryptography. The simulations indicate that only ~5% of radio-flaring UCDs within the local neighborhood have been discovered thus far, with another ~40 remaining to be discovered within 25 pc of the Sun. We review potential reasons for this success rate, and also assess the performance of the ISK technology.

207.02 — Lightcurve Asymmetries in *KEPLER* & *TESS* Eclipsing Binaries

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In this work, we study the O'Connell effect which describes the asymmetry in the out of eclipse maxima in Eclipsing Binary (EB) systems found in the *Kepler* and *TESS* fields. We calculate a Lomb-Scargle Periodogram for each object, and fit the resulting phase folded data with a twelve term Fourier fit. For each orbital cycle, the Fourier coefficients are used to quantify the asymmetry in the light curves by calculating the 'Lightcurve Asymmetry' (LCA) and the 'O'Connell Effect Ratio' (OER). We describe the time evolution of these asymmetries in hundreds of EBs. We generate starspot models for these systems using the eclipsing binary modeling software Binary Maker 3 (Bradstreet, 2005) and *PHOEBE* (Prsa, 2016), to test the hypothesis that the asymmetries are due to the presence of starspots on one or both components of the binary. Additionally, we classify each system as either Algol-type (EA), Beta-Lyrae type (EB), W-UMA type (EW), or as an 'irregular'-type system based on the criteria set by Rucinski (1997). Finally, we report on any correlation between the lightcurve asymmetries and eclipsing binary type.

207.03 — Continuing Investigation of Eclipsing Binaries at The BB&T Observatory of Thomas More University

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Eclipsing binaries are an ideal source of direct and precise measurements of stellar parameters. This ongoing study focuses on a subset of eclipsing binary systems of intermediate mass (roughly $3M_\odot$ to $10M_\odot$). High precision measurements of stellar parameters for this subset are rare, despite the importance of these stars in a variety of astrophysical phenomenon. Targets were identified based on varibility measured by the All Sky Automated Survey (ASAS). Based on these initial observations, eight targets have been chosen for dedicated spectroscopic and photometric study. We present the current status of eight targets with regard to photometric observations obtained at The BB&T Observatory of Thomas More University. We also provide initial estimates of the system parameters for those binaries with sufficient spectroscopic and photometric observations for binary modeling.

207.04 — Recombination Energy and Common Envelope Ejections

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Hydrodynamical simulations of binary systems undergoing common envelope evolution have generally failed to achieve the levels of envelope ejection and orbital inspiral needed to produce observed post-common envelope binaries, particularly binary white dwarfs. Energy released by hydrogen and/or helium recombination in the expanding envelope has been invoked as a potential source of energy, and recently Nandez and Ivanova have found using smoothed particle hydrodynamics (SPH) simulations that this mechanism may work if the energy can be trapped and used to do work. However, it is not clear whether this condition actually obtains in real systems. In particular, the efficiency of energy transport in removing this energy needs to be evaluated, as well as potential dynamical instabilities triggered by the existence of partial ionization zones, which could change the ejection criterion. To gain insight into this question, we are conducting adaptive mesh refinement (AMR) simulations of common envelopes with radiation diffusion and an equation of state that includes hydrogen and helium partial ionization. We present simulations of red giant-white dwarf systems, with parameters similar to those studied by Nandez et al., which are proposed as potential progenitors of the double-white dwarf system WD 1101+364. We discuss the efficiency of envelope ejection in these systems, examining its connection to the relative locations of the photosphere and partial ionization zones.

207.05 — A Search for X-ray Emitting Binary Stars in the Core of Omega Centauri

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We have searched for optical counterparts of Chandra sources within the core of the globular cluster Omega Centauri utilizing a catalog of photometry and proper motions derived from over 650 Hubble Space Telescope WFC3/UVIS exposures (Bellini et al. 2017). A total of 67 X-ray sources lie within the field of view of these HST images, 25 of which were reported for the first time by Henleywillis et al. (2018). Using a subset of six wide-band filters (F225W, F275W, F336W, F438W, F606W, and F814W) and two H-α filters (F656N and F658N), we construct color-magnitude diagrams to search for stars in the X-ray error circles whose properties are indicative of binarity, e.g., cataclysmic variables, coronally active binaries (BY Dra or RS CVn systems), and sub-subgiants or red stragglers. We identify ten new binary candidates and recover seven previously identified systems, providing independent confirmation that the latter have the properties expected of binaries. The binary candidates comprise nine candidate cataclysmic variables, five possible BY Dra systems, and three red stragglers, two of which may be associated with the metal-rich anomalous giant or subgiant branches of Omega Centauri. We also find evidence that four of the X-ray sources are foreground stars and two are probable active galactic nuclei in the background. We discuss the significance of these results in the context of efforts to understand the overall binary content and X-ray emissivity of globular clusters.

208 — iPoster Session: Instrumentation Space, Ground and Computation

208.01 — CH- and CHO-Composition in Comet 67P/Churyumov-Gerasimenko revealed by the Rosetta Mission

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Containing some of the most pristine material in our solar system, comets are unique objects of study: Their slow formation in the outer region of the protoplanetary disk protected them from high temperatures and led to preservation of the original material that had formed our solar system. Thus, profound understanding of the chemical composition of comets has the potential to provide answers for fundamental scientific questions such as evolution of our solar system or how life emerged on Earth. However, decryption of the chemical composition of comets is difficult. Spacecraft observations often consist of single encounters at relatively large distances only and even ground-based observational methods appear to be limited for some organic molecules due to weak dipole moments. A new scientific approach was established when the Rosetta spacecraft was sent to comet Churyumov-Gerasmienko (67P). For the first time a spacecraft performed in-situ measurements of the coma and nucleus while accompanied the comet on its way around the Sun. Onboard the spacecraft, the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) determined the chemical composition of the volatiles in the coma at various distances and angles between comet, Sun, and spacecraft, from arrival at the comet in 2014 until the final landing in 2016. Based on these data, the existence of a surprising amount and complexity of organics in the (semi-)volatile phase of the comet was demonstrated, with some molecules being detected for the first time ever in comets. After revealing this unexpected complexity, a key step in decryption of the exact composition was made by deriving the CH- and CHO-composition from the DFMS space data. The study presented here uses data from the ROSINA Double Focusing Mass Spectrometer and combines laboratory calibration at the Bernese calibration facility (CASYMIR) and space data analysis. This combination produces the first detailed identification and quantification campaign of CH- and CHO-bearing molecules in comet 67P. The results are compared to measurement and modelling results from other comets and the interstellar medium.

208.02 — WFIRST: Project Overview and Status

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The Wide-Field InfraRed Survey Telescope (WFIRST) will be the next Astrophysics strategic mission to follow JWST. The observatory payload consists of a Hubble-size telescope aperture with a wide-field NIR instrument and a coronagraph operating at visible wavelengths that employs state-of-the-art wavefront sensing and control. The Wide-field instrument is optimized for large area NIR imaging and spectroscopic surveys, with performance requirements driven by programs to study cosmology and exoplanet detection via gravitational microlensing. All data will be public immediately, and substantial general observer and archival research programs will be supported. The WFIRST Project is presently in Phase B, with the confirmation review expected in late 2019 or early 2020. Candidate observing programs are under detailed study in order to inform the mission design, but the actual science investigations will not be selected until much closer to launch. We will present an overview of the present mission design and expected performance, a summary of Project status, and plans for selecting the observing programs.

208.03 — High Energy Exoplanet Science in the Next Decade and Beyond

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I present a comparison of high energy studies of exoplanet targets which can be done with the next generation of X-ray telescopes. Specifically, I will show the immediate and decisive impact of XRISM, SEEJ and Athena. Future studies will focus increasingly on other planetary systems and the exoplanet science which comes from understanding the interactions between the stellar magnetic fields and the planetary magnetic fields. Observations enabled by planned grating spectrometers such as those aboard Arcus and Lynx will allow us to capture dynamic changes in these environments, furthering our knowledge of the energetic side of stellar ecosystems. By the late 2020's and 2030's characterization of the high energy environments of specific exoplanets will be a necessary step in our evaluation of their current and future prospect for habitability. All four of these missions will be able to uniquely contribute to our understanding of these systems.

208.04 — Recent Scientific Highlights from the Stratospheric Observatory for Infrared Astronomy (SOFIA)

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The Stratospheric Observatory for Infrared Astronomy (SOFIA) is currently the only observing facility offering a window into the whole mid- and far-IR spectrum (5-600 microns). Its ever evolving suite of instruments offers high-speed mapping, low and high-spectral resolution modes (up to R=10^8), and recently added polarimetric capabilities on the HAWC+ far-IR camera. This unique and upgradable set of instruments, combined with the ability for the telescope to target Northern and Southern sources, makes SOFIA an essential facility for the astrophysics community, highly complementary to HST/JWST and ALMA. Over 6 observing cycles, SOFIA observations have targeted very diverse sources such as Solar System objects, young stellar objects and disks, planetary nebulae, star-forming regions (galactic and extra galactic) and AGNs. Such observations address a variety of science cases, including the morphology of magnetic fields on galactic scales, ISM gas chemistry, PAH spectroscopy, and atomic/ionized emission in massive star-forming regions. This poster summarizes the most recent high-profile SOFIA-enabled scientific results, focusing on dust imaging and polarimetry in nearby active galaxies, supernovae remnants, and galactic star-forming regions. The two large proposals recently accepted through the Legacy Science Proposal, which aims at providing high-value products to the astronomical community, will also be described. Finally, we present the capabilities of HIRMES, the third generation mid/far-IR imager and spectrometer instrument planned for commissioning in 2020, and HIRMES' future contribution to the study of the mass and composition (including ice and gas-phase water content) of protoplanetary disks.

208.05 — Absolute flux calibration and characterization of the SOFIA FIFI-LS integral field spectrometer.

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We present the absolute flux calibration and characterization of the Far-Infrared Field-Integral Line Spectrometer (FIFI-LS) of SOFIA. The work is based on observations made in the laboratory with an internal calibrator and on observations of planets, moons, and asteroids as absolute flux calibrators made in the last 5 years. Two sets of responses are presented, before and after the filter window change made at the end of 2017 to improve the sensitivity at 52 μm.

The relative spectral response of each detector of the FIFI-LS arrays is derived using the internal calibrator while the illumination of the arrays is estimated through sky flats. The linearity of the array response was studied using several observations of bright sources.

We find that the deviation from linearity of the FIFI-LS arrays is typically less than 1%. The flux calibration accuracy is estimated to be 10% or better across the entire wavelength range of the instrument. Repeatability of better than 5% is found though multiple measurements of the same calibration source.

208.06 — A Coordinated Ground- and Space-Based Observing Campaign to Measure $CO_2$and CO Emission in C/2016 R2 (PANSTARRS)

Olga Harrington[1]; Adam McKay[3]; Michael A. DiSanti[3]; Michael S. Kelley[4]; Anita L. Cochran[2]; Neil Dello Russo[5]; Maria Womack[6]; Kacper Wierzchos[1]; Nicolas Biver[7]; James M. Bauer[4]; Ronald J. Vervack[5]; Boncho P. Bonev[8]; Erika L. Gibb[9]; Nathan Roth[9]; Hideyo Kawakita[10]

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Comets are similar to time capsules in that they give hints about the characteristics of the solar system as it was forming. They are composed of rock, dust, water ice, frozen carbon dioxide, carbon monoxide, methane, and ammonia, where there is typically more carbon dioxide (CO_2), than carbon monoxide (CO). Comet C/2016 R2 is a special example of a comet that produced an unusual chemical composition profile, with large amounts of CO, CO+, N_2+ with very little else (McKay et al. 2018; Wierzchos & Womack 2018; Biver et al. 2018). CO_2 is also often abundant in comets; however, it can only be observed from space due to significant telluric absorption from the Earth's surface. In order to measure the CO_2 production rate, we carried out a coordinated observing campaign using the Arizona Radio Observatory Submillimeter 10-m telescope, the IRAC instrument on the Spitzer Space Telescope, iSHELL on the NASA IRTF, and the Institut de Radioastronomie de Millimetrique 30-m telescope during January-February 2018. CO was strongly detected from the ground-based spectra and there is a very strong presence of gaseous emission in the 4.5 micron IRAC channel, which is sensitive to both CO_2 and CO emission. We completed a comprehensive analysis of the SMT, iSHELL, and IRAM observations in order to estimate the CO contribution to the observed Spitzer 4.5 micron channel fluxes. This is crucial to extract the CO_2 abundance from the Spitzer imaging. We will present and discuss our CO and CO_2production rates, and explain our program to measure pre-perihelion (Feb 2018) and post-perihelion (June 2019) values of the CO_2/CO ratios. This work makes use of Director's Discretionary Time observations obtained on Spitzer, IRTF, ARO, and IRAM and we thank these observatories for granting our group DDT time to conduct these observations. This work is funded through the NASA NPP program, administered by USRA, by NSF grant AST-1615917 to M.W. and a Genshaft Family Doctoral Fellowship to O.H.P.

208.07 — Multibeam Receiver System and Key Science Programs of TRAO

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Taeduk Radio Astronomy Observatory (TRAO) is equipped with a main control computer with Vx-Works operating system, a new receiver system, and a new backend system. The new receiver system(SEQUOIA-TRAO) is equipped with high-performing 16-pixel MMIC pre-amplifiers in a 4x4 array, operating within 85∼115 GHz frequency range. The system temperature ranges from 150 K (85 GHz) to 400 K (115 GHz). The 2nd IF modules with the narrow band and the 8 channels with 4 FFT spectrometers allow to observe 2 frequencies simultaneously within the 85∼100 or 100∼115 GHz bands for all 16 pixels 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 85 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. We welcome and support invaluable observation programs.

208.08 — Evaginated Apodization Coronagraph

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High contrast imaging of faint objects nearby the bright objects is a challenging task due to it requires a high angular resolution and high dynamic range detections concurrently. For imaging older and less massive are required spectroscopic and achromatic high contrast imaging. Moreover, large broadband is extreme challenging in visible and near-infrared. The coronagraph coupled with extreme adoptive optics is being operated to a high-contrast imaging for a direct observation of exoplanets which will provide their chemical composition of atmospheres and their temperature. The essential scheme of the EAC is that the apodization carried out by excluding evaginated images after passing a set of axicon lenes. The prerequisite of completely evaginated of the entire entrance pupil of the EAC is that the distance between two ALs should be setting the refracted beam at the close to the apex of the first AL is reached to the outmost surface rim of the given second AL. Once this condition is satisfied, the central bright star light has been so relocated to the rim of the image which is easy to cut off by a variable aperture iris, thoroughly without losing any image of the faint objects. The laboratory based axicon-lens coronagraph imaging support the symbolic computation results which has potential in direct imaging for finding exoplanet and various astrophysical activities. We report, an evaginated apodization coronagraph(EAC) method using the axicon-lenses, which achieve the small IWA and high contrast imaging with large broadband imaging in visible to near-infrared. Furthermore it insensitive to the stellar angular size and the setup of the coronagraph is simple to build and is durable to operate. Moreover it can be transported the planets images to a broadband spectrometric instrument that able to investigate the constituent of the planetary system.

208.09 — The Preliminary CatWISE Catalog

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The Preliminary CatWISE catalog consists of 957,285,574 sources over the entire sky selected from WISE and NEOWISE survey data at 3.4 and 4.6 microns (W1 and W2) collected from 2010 to 2016. This dataset includes four times as many exposures and spans over ten times as large a time baseline as the AllWISE catalog. CatWISE adapts AllWISE software to measure the sources in co-added images created from six month subsets of these data, each representing one coverage of the inertial sky, or epoch. The catalog includes the measured motion of sources in 8 epochs over the 6 year span of the data. From comparison to Spitzer, the SNR 5 Vega magnitude limits are W1=17.58 and W2=16.43, vs. W1=16.90 and W2=15.95 for AllWISE. From comparison to Gaia, the motions are ten times more accurate than those from AllWISE. The Preliminary CatWISE catalog is available to the astrophysics community at `https://catwise.github.io`.

208.10 — Searching for Low-mass Stellar and Sub-stellar objects in the *JWST* North Ecliptic Pole Time-Domain Field

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The *James Webb Space Telescope* (*JWST*) North Ecliptic Pole (NEP) Time-Domain Field (TDF) is a 14′ diameter region of the sky selected to be ideal for ultra-deep ($m_{AB} \sim 29$ mag) time-domain science with *JWST* (Jansen & Windhorst 2018), that is being developed as a community field. Located within *JWST*'s northern Continuous Viewing Zone, it can be observed year-round, is devoid of detector saturating stars, has low Galactic foreground extinction, and will be targeted by GTO program 1176 (Windhorst) with NIRCam and NIRISS. It is the only region in the sky where *JWST* can observe a clean extragalactic deep survey field of this size at arbitrary cadence and orientation, enabling 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 (AGN) to brown dwarf atmospheres, as well as proper motions of extreme scattered Kuiper Belt Objects and comets beyond the distance of Neptune, and of nearby Galactic brown dwarfs, low-mass stars, and ultracool white dwarfs. In anticipation of *JWST*'s launch in 2021, a wealth of ancillary data across the electromagnetic spectrum (X-ray–radio) has already been collected. This includes deep (~0.9 muJy rms) VLA 3GHz radio observations (B+A configuration) and LBT/LBC *Ugrz* ($m_{AB} \sim 26$ mag) and MMT/MMIRS *YJHK*s ($m_{AB} \sim 24.5$–22 mag) photometry of the entire *JWST* NEP TDF, as well as *HST*/WFC3+ACS UV–Visible observations of the central r<~5′. Since a major science driver for this field is the study of AGN activity, and since Galactic late-type stars and brown dwarfs are often identified within samples of AGN candidates, we here report on an analysis of the 3GHz radio and LBT/LBC and MMT/MMIRS visible–near-IR observations to search for such late-type stellar and substellar sources. We also aim to study their properties, with particular emphasis on the possible detection of faint radio-emission (coronal, auroral, flares) of either individual objects or (through stacking) of the populations. We furthermore report on the progress of *HST*-GO-15278, the final two visits of which executed flawlessly, and preliminary analysis thereof.

209 — iPoster Session: Laboratory Astrophysics Division (LAD)

209.01 — Reverse Current Model for Coronal Mass Ejection Cavity Formation

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We report here a new model for explaining the three-part structure of coronal mass ejections (CMEs). The model proposes that the cavity in a CME forms because a rising electric current in the core prominence induces an oppositely directed electric current in the background plasma; this eddy current is required to satisfy the frozen-in magnetic flux condition in the background plasma. The magnetic force between the inner-core electric current and the oppositely directed induced eddy current propels the background plasma away from the core, creating a cavity and a density pileup at the cavity edge. The cavity radius saturates when an inward restoring force from magnetic and hydrodynamic pressure in the region outside the cavity edge balances the outward magnetic force. The model is supported by (i) laboratory experiments showing the development of a cavity as a result of the repulsion of an induced reverse current by a rising inner-core flux-rope current, (ii) 3D numerical magnetohydrodynamic (MHD) simulations that reproduce the laboratory experiments in quantitative detail, and (iii) an analytic model that describes cavity formation as a result of the plasma containing the induced reverse current being repelled from the inner core. This analytic model has broad applicability because the predicted cavity widths are relatively independent of both the current injection mechanism and the injection timescale.

209.03 — Laboratory plasma experiments to test photoionized plasma models

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We discuss an experimental effort to create and study astrophysically relevant photoionized plasmas in the laboratory. Conditions relevant to the extreme environments in x-ray binaries, accretion disks around black holes, and active galactic nuclei have long been experimentally inaccessible. Astronomers looking to understand such objects rely on the accuracy of the photoionization models they employ, yet we are only beginning to have the ability to probe this regime experimentally with devices such as the Z-Machine at Sandia National Laboratories. Our experiment utilizes the intense x-ray flux emitted at the collapse of a Z-pinch to heat and backlight a neon photoionized plasma contained within a cm-scale gas cell with atom number densities of 10^{17} to 10^{18} cm^{-3}. The broadband x-ray flux at the gas cell at the peak of the x-ray drive is of order 10^{12} W/cm^2 producing an order of magnitude range in ionization parameter from about 5 to 50 erg*cm/s, depending

on gas fill pressure. The resulting plasma conditions are determined using K-shell line absorption spectroscopy from a KAP crystal spectrometer capable of capturing both time-integrated and time-gated transmission spectra. Analysis of these spectra yields ion areal densities and the charge state distribution, which can be compared with simulation results from atomic kinetics codes. In addition, the electron temperature is extracted from level population ratios of nearby energy levels in Li-like ions, which can be used to test heating models of photoionized plasmas as well.

This work was sponsored in part by DOE NNSA HEDLP grant DE-NA0003875, DOE Office of Science Grant DE-SC0014451, the Wootton Center for Astrophysical Plasma Properties, and the Z Facility Fundamental Science Program of SNL.

209.04 — Relativistic Atomic Structure of the Au IV Isoelectronic Sequence: opacity data for kilonova ejecta

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Direct detection of gravitational waves (GW) on Aug. 17, 2017, propagating from a binary neutron star merger, opened the era of GW astronomy. The ejected material from neutron star mergers is called "kilonova" or "macronova" which is a good candidate for optical and near infrared follow-up observations after the detection of GWs. The kilonova provided the first direct evidence for the synthesis of heavy nuclei through the rapid neutron capture process or so called r-process. Although properties of the emission are largely affected by opacities in the ejected material, available atomic data for r-process elements are still limited. The aim of our research is to alleviate this situation, in this regard we are using GRASP0 [1,4] and GRASP2K [2] to obtain energy levels and transition properties then generate reliable line lists for a range of r-process elements (Re-Pt). Here, Au IV, as well as its low-charged isoelectronic sequence members, Os I, Ir II, Pt III, , are computed and compared against available theoretical and experimental data [3]. The Au IV results are used to simulate emission spectrum to interpret the Compact Toroidal Hybrid experiment with a gold-platted probe. This work was partially supported by NSF grant 1816984

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209.05 — Measuring the $^{15}N(\alpha,\gamma)^{19}F$ reaction using a Bubble Chamber.

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Radiative capture reactions, such as (α,γ), (p,γ) and (n,γ), are of fundamental importance to the study of nucleosynthesis of elements in stellar cores, supernovae, etc. In the laboratory, these reactions are usually measured by bombarding gas targets or very thin films with particle beams. The low density of these targets and the sensitivity to background from environmental and cosmic sources can lead to long running times. In this contribution we explain a method - using a single fluid bubble chamber to measure nuclear reaction cross sections. Here determining the cross section of the $^{15}N(\alpha,\gamma)^{19}F$ reaction relevant to the synthesis of fluorine in AGB stars (possibly also in Wolf-Rayet stars). The higher density of the fluid and measuring the time-reversed reaction increases the luminosity of the experiment by several orders of magnitude. We have measured the cross section of the photodisintegration process $^{19}F(\gamma,\alpha)^{15}N$ by bombarding a superheated fluid of C_3F_8 with Bremsstrahlung γ rays produced from the electron injector at Jefferson Laboratory reaching cross sections of the time-reversed $^{15}N(\alpha,\gamma)^{19}F$ reaction of about 80 picobarn.

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209.06 — Searching for Contemporary Supernova Dust in Deep-Sea Sediments

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The short-lived radioisotope 60Fe is synthesized predominantly in supernovae and is not produced efficiently by other mechanisms like cosmic-ray spallation. An excess of 60Fe has been detected in deep-sea sediments, ferromanganese crusts, and in Apollo 12 lunar soils. These measured excesses in 60Fe are consistent with an injection from a nearby supernova ~2 Myr ago.

The solar wind and interplanetary magnetic field would have effectively shielded the Solar System from gas and plasma ejected from a nearby supernova, so it was likely supernova dust grains that carried the 60Fe signature to Earth and the Moon. Graphite and silicon-carbide dust grains from this supernova, phases that are well-studied in supernova grains that predated the formation of the Solar System, would have likely survived atmospheric entry. These grains would represent an extremely valuable sample of contemporary supernova dust that can be studied using high-precision laboratory techniques and compared to presolar (>4.6 Gyr old) supernova dust.

Here we describe our efforts to identify contemporary supernova dust in deep-sea sediments.

209.07 — Plume profile studies of nanosecond laser-induced desorption of water ice - *amorphous versus crystalline* -

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In the interstellar medium and within our solar system, ice is present in diverse locations ranging from molecular clouds to the Jovian moon Europa. There have been various efforts to develop new techniques to replicate these environments and study these ices in the laboratory. From an astrochemical point of view, the development is key for understanding how the energetic processing of ice can lead to molecular complexity. From a planetary science point of view, the development is driven to investigate novel instrumentation for future space exploration missions. The Jovian moon Europa is of particular interest for the search of extraterrestrial life within our solar system. At NASA's Jet Propulsion Laboratory, we have used the two-color Laser Ablation Ionization Mass Spectrometer system to study such ice-surface analogues.[1,2] The system has the capabilities to simulate relevant conditions, encountered in relevant environments. The structure of the ice depends on the deposition temperature. IR laser desorption combined with multi-photon ionization mass spectrometry, provides insights in the desorption dynamics of the plume. We are capable of varying the wavelength of the IR laser, from 2700-3100 nm. By introducing different species in low abundances into the ice structure, we can study if these molecules follow the same trend in extraction time as the water molecules. These fundamental investigations are essential for understanding the processes at play, and gaining insights into the nanosecond laser-induced desorption process.

1. Henderson, B.L. and Gudipati, M.S., The Journal of Physical Chemistry A, V.118, I.29. (2014) 2. Paardekooper, D.M. et al. Rev. Sci. Instrum., 85, 104501. (2014)

210 — iPoster Plus VI: (SPD), Flares

210.01 — On the Origin of Quasi-periodic Fast-mode Propagating Wave Trains (QFPs): A Statistical Survey

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The magnetized solar corona hosts a variety of waves that are physically important and can serve as useful diagnostic tools. One type of such coronal waves are Quasi-periodic Fast-mode Propagating wave trains (QFPs), which were first detected in extreme ultraviolet (EUV) by the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO). QFPs are not uncommon and are generally associated with some, but not all solar flares and/or coronal mass ejections (CMEs). To search for physical conditions that can contribute to QFP production, we carried out a systematic survey of QFPs from the full SDO mission. We found that about 1/5 of global EUV waves were associated with QFPs. We

also conducted a comparative study of two active regions (ARs) visible between October and November 2014, AR12192 and AR12205, with very different levels of QFP activity. AR12205 produced less flares but more QFPs, which were all associated with blow-out, eruptive flares and global EUV waves. In contrast, AR12192 produced more (mostly confined) flares, but with virtually no QFPs and less CMEs. This suggests that blow-out eruptions could be a necessary, but not sufficient condition for QFP production and/or detectability.

210.02 — Quasi-Periodic Pulsations Observed in White Light at the Loop Top of the SOL2017-09-10 X8.2 Flare

Junwei Zhao[1]; Wei Liu[1]
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An X8.2 flare occurred on September 10, 2017 near the Sun's west limb. Simultaneously with the observations of the SDO/AIA's multiple UV/EUV channels, the continuum intensity of the SDO/HMI also observed the evolution of the post-flare loop above the solar limb. This gives us a rare opportunity to analyze the post-flare loop in visible light, UV, and EUV channels. Quasi-periodic pulsations, with a period close to about 8 minutes, are found in all these channels during the rise of the loop top. We study the spatial and temporal relations of the pulsations observed in different wavelengths, and find that EUV pulsations occurred about 2-3 minutes earlier, and 2-6 Mm higher in altitude, than the pulsations observed in UV and white light. While the UV observations show many similarities in the pulsations with the white light observations, the UV intensity decayed with the rise of the loop but the white light intensity grew for about 20 more minutes. These observations help shed light on our understanding of the magnetohydrodynamics of the flare's loop-top, as well as the emission mechanism of the white light off the solar limb.

210.03 — Radio Spectroscopic Imaging of Solar Flare Termination Shocks: Split-band Feature and A Second Possible Event

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[3] *Center for Astrophysics Harvard-Smithsonian (Cambridge, Massachusetts, United States)*
[4] *National Radio Astronomy Observatory (Charlottesville, Virginia, United States)*

Solar termination shocks (TSs) can form above the looptop when reconnection outflows that impinge upon newly reconnected flare arcades exceed the local fast-mode magnetosonic speed. TSs have been suggested as one of the promising drivers for particle acceleration in solar flares, yet observational evidence remains rare. By utilizing radio dynamic spectral imaging of decimetric stochastic spike bursts (SSBs) observed during a C1.9 eruptive flare on 2012 March 3, Chen et al. (2015) found that the bursts were associated with a dynamic TS-like feature above the looptop. They also showed evidence for the TS as an electron accelerator. One piece of observational evidence that strongly supports the TS interpretation is the split-band feature – a phenomenon well-known in type II radio bursts associated with CME-driven shocks, one interpretation for which attributes to radio emission from both the upstream and downstream side of the shock. We perform detailed spectral imaging analysis of the split-band feature in the 2012 March 3 SSB event, and find evidence that supports the shock upstream-downstream interpretation. We also report another SSB event observed during an M8.4 eruptive flare on 2012 March 10, and show that the radio centroids of the SSBs form a similar shock-surface-shaped structure to the earlier event, located above the reconnected flare arcades and below supra-arcade plasma downflows.

210.04 — Joint GST and EOVSA Observation of an M1.4 Flare on 2017 September 6

Yuqian Wei[1]; Bin Chen[1]; Sijie Yu[1]; Haimin Wang[1]
[1] *New Jersey Institute of Technology (Newark, New Jersey, United States)*

We study an M1.4 class flare occurred shortly after the X9.3-class flare on 2017 September 6 in NOAA active region (AR) 12673. The flare was well observed by the Expanded Owens Valley Solar Array (EOVSA), the Goode Solar Telescope (GST) at the BBSO, Hinode, and RHESSI. We find a partial eruption of a flux rope in GST H-α images during the flare, with coronal counterparts seen in SDO/AIA images. Microwave spectral imaging observations from EOVSA provide unique measurements of the coronal magnetic field and energy distribution of the nonthermal electrons accelerated to mildly relativistic energies. We compare the location and morphology of the microwave source with H-α, EUV, and X-ray data, and discuss implications for energy release and electron acceleration in this flare.

211 — iPoster Plus VII: Stars & Friends

211.01 — System Parameters for the Eclipsing Binary Systems BD+11º3569 and HD 51082

Wesley Ryle[1]; Kylie Anderson[1]; Kelsey Etherton[1]; Cristi Farwick[1]; Sierra O'Bryan[1]; Terri Perrino[1]; Raymond Whitehill[1]
[1] *Thomas More University (Crestview Hills, Kentucky, United States)*

We present the results from a combined spectroscopic and photometric in-depth study of the binary systems BD+11º3569 and HD 51082. Fits to Johnson V , Cousins R and I photometry and radial velocities yield system parameters for each star in the binary systems with uncertainties of less than 2%. Both systems include intermediate mass stars for which precise, direct measurements of mass, radii, and temperature are lacking. These systems were initially selected based on photometric measurements from the All Sky Automated Survey (ASAS), with subsequent spectroscopic and dedicated photometric measurements carried out by the authors.

211.02 — Multi-messenger Search for Binary Neutron Star Mergers

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The observation of the binary neutron star merger GW170817 heralded the age of multi-messenger astronomy. We'll discuss the joint observation of GW170817 and GRB 170817A and how combining information from multiple channels can improve the search for the most distant binary neutron star mergers. Finally, we'll explore results from a multi-messenger search using public LIGO and Fermi data.

212 — NASA Astrophysics Science SmallSat Studies

212.01 — XQCSat - X-Ray Quantum Calorimeter Satellite

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[4] *Blue Canyon Technologies, Inc. (Boulder, Colorado, United States)*

We are developing a small satellite mission concept, the X-ray Quantum Calorimeter satellite (XQCSat), capable of performing high-resolution X-ray spectroscopy of diffuse gas in the interstellar medium within the Galaxy and the Galactic halo. The high spectral resolution (6 eV) of XQCSat enables unambiguous measurement of the physical state of hot gas from individual spectral lines, while its wide field of view provides more than two orders of magnitude improvement in the study of diffuse emission relative to the microcalorimeter flown on Hitomi. XQCSat will study stellar feedback, how energy from stars and supernovae affects the surrounding stellar and galactic environment and transports metal produced in stars, providing insight to the evolution and structure of galaxies. XQCSat will probe the distribution and dynamics of hot gas in the halo of the Milky Way to determine how it is heated and whether it contributes significantly to the total mass of the Milky Way. Key to XQCSat is development of a small-satellite compatible cryostat and adiabatic demagnetization refrigerator capable of cooling the focal plane detector array to 50 mK. Demonstration of that capability will enable small satellite missions in other wavebands such as the far-infrared.

212.02 — Dark Cosmology: Investigating Dark Matter and Exotic Physics using the Redshifted 21-cm Global Signal with the Dark Ages Polarimeter Pathfinder (DAPPER)

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We report on the results of a NASA-funded Astrophysics SmallSat concept study for a proposed lunar-orbiting experiment, the Dark Ages Polarimeter PathfindER (DAPPER), that is designed to observe the unexplored Dark Ages epoch of the early Universe. The Dark Ages, probed by the highly redshifted 21-cm neutral hydrogen global signal, is the ideal epoch for a new rigorous test of the standard LCDM cosmological model. DAPPER will search for divergences from the standard model that will indicate new physics such as heating or cooling produced by dark matter. A broad absorption trough in the redshifted 21-cm spectrum is expected during the Dark Ages, prior to the formation of the first stars and thus determined entirely by cosmological phenomena. DAPPER will observe this pristine epoch

(17-38 MHz; z~83-36), and will measure the amplitude of the 21-cm spectrum to the level required to distinguish (at >5-σ) the standard cosmological model from that of additional cooling derived from recent EDGES results. The main challenge of this measurement is the removal of bright foregrounds. DAPPER is designed to overcome this by utilizing two pioneering techniques: (1) a polarimeter to measure polarization induced by the anisotropic foregrounds and large antenna beam to aid in the separation of the foregrounds from the isotropic, unpolarized global signal, and (2) a pattern recognition analysis pipeline based on well-characterized training sets of foregrounds from sky observations, instrument systematics from simulations and laboratory measurements, and signals from theoretical predictions. End-to-end simulations of the DAPPER instrument including thermal noise, systematics from the spectrometer/polarimeter and the beam-averaged foreground, along with 21-cm models which include added cooling meet our sensitivity requirements to separate the standard cosmological models from ones that point toward new physics. DAPPER's science instrument consists of dual orthogonal dipole antennas and a tone-injection receiver based on high TRL components from the Parker Solar Probe/FIELDS, CURIE, and WIND/WAVES. DAPPER will be deployed into a frozen 50x125 km lunar orbit to provide 4615 hours of radio-quiet integration over a 26 month lifetime.

212.03 — The Gravitational-wave Ultraviolet Counterpart Imager (GUCI) Network

Stephen B. Cenko[1]
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The Gravitational-wave Ultraviolet Counterpart Imager (GUCI) network is a SmallSat mission concept designed to identify and characterize the early (dt < 1 d) UV emission from binary neutron star mergers. GUCI is comprised of 2 independently operating 12U cubesats in low-Earth orbits, each equipped with a wide-field (~ 50 square degrees) UV imager. We will promptly uplink sky localizations of binary neutron star mergers from gravitational wave detectors to the spacecrafts. Unlike ground-based optical observatories that suffer from visibility (e.g., waiting for night to begin observing) and weather constraints, GUCI will begin imaging of gravitational wave localizations within one hour (on average). Each satellite will have a distinct bandpass, but will otherwise be identical. The multi-filter UV coverage and high cadence (95 minutes) will enable us to determine the origin of the early UV-bright emission from binary neutron star mergers - such observations cannot be accomplished from the ground, due to atmospheric transmission (bandpass) and visibility constraints (cadence).

While not following up binary neutron star mergers, GUCI will conduct the first synoptic survey of the UV transient sky, imaging 1500 square degrees every 3 hours to a depth of 19.0 mag (AB). GUCI transient discoveries will address key Decadal Survey science questions such as how super-massive black holes accrete material and influence their surroundings, and which massive stars give rise to the different classes of core-collapse supernovae. It will naturally complement the Large Synoptic Survey Telescope and Square Kilometer Array in these time-domain studies.

The key enabling technology for GUCI is the development of delta-doped CCD detectors, providing an order-of-magnitude improvement in throughput over the microchannel plates used for GALEX and the UVOT on Swift. Even with the modest aperture required by a cubesat form factor, GUCI will achieve sufficient sensitivity to detect binary neutron star mergers out to at least 100 Mpc.

In this talk we describe the scientific objectives, instrument and mission implementation for the GUCI concept.

212.04 — MASS (MicroArcsecond Small Satellite)

Michael Shao[1]
[1] *JPL (Pasadena, California, United States)*

MASS is an ESPA class Mission that is one of the NASA funded AS3 studies. It uses with a 35cm aperture and a large format CMOS sensor designed to achieve 4~5 microarcsec astrometric precision in ~ 1hr on bright nearby stars against ~100 nearby reference stars as bright as 10 mag within a ~1/2 degree FOV. The scientific goal is to search for exoplanets down to 1 Earth mass around a ~1/2 dozen of the nearest stars and up to ~20 stars down to 2 Earth mass in the habitable zone. Transit searches favor planets with orbital period of days. This astrometric search compliments the transit searches for exo-Earths because astrometry is more sensitive to planets with oribital periods of ~ 1 year around FGK stars. This high precision is achieved through a laser calibration of the focal plane detector at the ~1e-4 pixel level, along with a highly stable thermal design for both the telescope and focal plane, and a diffractive pupil to measure the distortion of the optics. While technological advances allow such high precision, another significant enabler for this type of mission is the dramatically lower cost of ESPA Class spacecraft that are now becomming available and rather popular. ESPA class spacecraft with up to 250Kg mass 400W and sub-arcsec pointing stability have dramatically dropped in cost in the recent past and enable very capable science missions for a fraction of a SMEX or MIDEX.

212.05 — Placeholder: Bruce Macintosh

212.06 — SEEJ: Smallsat Exploration of the Exospheres of Nearby Hot Jupiters

Scott J. Wolk[1]
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The first detected exoplanets found were "Hot Jupiters"; these are large Jupiter-like planets in close orbits to their host star. The stars in these so-called "Hot Jupiter systems" can have significant X-ray emission and the X-ray flux likely changes the evolution of the overall star-planetary system in at least two ways:

(1) the intense high energy flux alters the structure of the upper atmosphere of the planet – in some cases leading to significant mass loss;

(2) the angular momentum and magnetic field of the planet induces even more activity on the star, enhancing its X-rays, which are then subsequently absorbed by the planet.

If the alignment of the systems is appropriate, the planet will transit the host star. The resulting drop in flux from the star allows us to measure the distribution of the low density planetary atmosphere.

We describe a science mission concept for a Smallsat Exploration of the Exospheres of hot Jupiters (SEEJ; pronounced "siege"). SEEJ will monitor the X-ray emission of nearby X-ray bright stars with transiting hot Jupiters in order to measure the lowest density portion of exoplanet atmospheres and the coronae of the exoplanet hosts. SEEJ will use revolutionary Miniature X-ray Optics (MiXO) and CMOS X-ray detectors to obtain good collecting area and high sensitivity in a low mass, small volume and low-cost package. SEEJ will observe scores of transits occurring on select systems to make detailed measurements of the transit depth and shape which can be compared to out-of-transit behavior of the target system. The depth and duration of the of the flux change will allow us to characterize the exospheres of multiple hot Jupiters in a single year. In addition, the long baselines (covering multiple stellar rotation periods) from the transit data will allow us to characterize the temperature, flux and flare rates of the exoplanet hosts at an unprecedented level. This, in turn, will provide valuable constraints for models of atmospheric loss.

212.07 — The Virtual Telescope for X-ray Observations (VTXO)

John Krizmanic[1]
[1] *CRESST/NASA/GSFC/UMBC (Greenbelt, Maryland, United States)*

The Virtual Telescope for X-ray Observations (VTXO) will use lightweight Phase Frensel Lenses (PFLs) with near diffraction-limited performance in a virtual X-ray telescope with ∼1 km focal length and with ∼50 milli-arcsecond angular resolution. While laboratory tests of PFLs have achieved near diffraction-limited angular resolution in the X-ray band, they require long focal lengths to achieve this quality of imaging. VTXO is formed by using precision formation flying of two SmallSats: a smaller OpticsCraft that houses the PFLs and a larger DetectorSat that contains an X-ray camera and propulsion for the formation flying. The baseline flight dynamics uses an elliptical orbit to allow the formation to hold in an inertial frame around perigee for an extended period. VTXO's fine angular resolution enables measuring the environments closer to the central engines in compact X-ray sources, allowing for the study of the effects of dust scattering halos nearer to the central objects in Cygnus X-3 and GX 5-1, the search for dust scattering echoes nearer to the central object in X-ray transients, and the search for sub 0.1 arcsecond structures in the plerion nebula around the Crab pulsar and in the wind environments ambient to bright X-ray binaries such as Cyg X-1. The fine angular resolution could also potentially resolve structure in the enigmatic Be star Gamma Cassiopeiae, resolve X-ray sources in regions of high stellar density, and allow for studying the effects of space weather on nearby exoplanets. The VTXO SmallSat and instrument designs, mission description, and science performance will be described.

212.08 — Concept Study for the *HREXI* SmallSat Pathfinder (*HSP*) Mission

Jonathan Grindlay[1]*; JaeSub Hong*[1]*; Branden Allen*[1]*; Daniel Violette*[1]*; Fiona Harrison*[2]*; scott barthelmy*[3]*; Benjamin Cervantes*[4]*; Marc Fouquet*[5]
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X-ray Time-domain Astrophysics (TDA) enables a wide range of high priority studies: from the birth of stellar mass black holes (LGRBs) at high redshifts to the tidal disruption of stars and production of relativistic jets by dormant supermassive black holes in galaxies, to name a few. We describe our AS3 Concept Study for the High Resolution Energetic X-ray Imager (*HREXI*) SmallSat Pathfinder (*HSP*) mission, a 3 –200 keV coded aperture telescope with a 36°x36° FoV. *HSP* is a Pathfinder for a proposed future 4pi X-ray Imaging Observatory (*4piXIO*), the first *full-sky-continuous-imaging* survey. *HSP* has 960 $cm^2$of imaging CdZnTe (CZT) detectors with 15-150 keV sensitivity similar to Swift/BAT plus 3-15 keV coverage *not* covered by BAT. The 4.6 arcmin resolution gives ≤28 arcsec source positions. *HSP* will survey the Galactic Bulge for flaring of quiescent BH-LMXBs and black hole candidates down to Lx(3-30 keV) =1.5 x 10^{33} erg/s, that of the BH-LMXB V404Cyg in quiescence. *HSP* will survey 2 nearby (0.5 kpc) OB associations for low-luminosity BHC-HMXBs accreting from weak-wind main sequence O8-9V stars, as found with *NuSTAR* in the Carina OB2 association (Grindlay+2019, in prep). *HSP* would reach Lx(3-30 keV) = 6 x 10^{30}erg/s (∼15X lower than the *NuSTAR* candidate). Both the qBHC-LMXBs and BHC-HMXBs are recognized by their detection at energies >10 keV. There should be ∼30X more weak-wind BH-HMXBs than Cyg X-1 systems, the ratio of O star main sequence/super-giant lifetimes. The *HSP* compact coded aperture telescope mounts on a Blue Canyon Technologies Microsat-S5 spacecraft which provides ∼1 arcmin inertial pointing with continuous ∼5arcsec aspect data from 2 star trackers. Two body-mounted solar panels deliver the 69 W instrument/spacecraft power, and Xband patch antennas downlink prompt positions and fluxes for GRBs and transient alerts and full data (0.6GB/day) in several NEN passes per day. The 96kg payload mass is mounted within a standard ESPA volume for a Rideshare launch into a 25 –30°inclination, 600 km LEO orbit. Positions and fluxes for all prompt GRBs and Transients would be immediately available by GCNs, followed by full light curves and spectra as they are processed and posted on the *HSP* mission public web-site.

212.09 — ISCEA: Infrared SmallSat for Cluster Evolution Astrophysics

Yun Wang[1]
[1] California Institute of Technology (Pasadena, California, United States)

ISCEA (Infrared SmallSat for Cluster Evolution Astrophysics) is a small space mission that will study the evolution of the Universe during the peak of galaxy formation. I will describe the ISCEA mission concept, and the findings of the NASA-funded concept study.

213 — Laboratory Astrophysics Division Meeting (LAD): Bridging Laboratory & Astrophysics: Molecules and Spitzer II

213.01 — LAD Early Career Award: GOTHAM and ARKHAM: First Results from Programs to Explore Aromatic Chemistry at the Earliest Stages of Star Formation

Brett A. McGuire[1,2]
[1] National Radio Astronomy Observatory (Charlottesville, Virginia, United States)
[2] Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)

I will present an overview of the GOTHAM (GBT Observations of TMC-1: Hunting Aromatic Molecules) and ARKHAM (A Rigorous K-band Hunt for Aromatic Molecules) projects on the 100 m Robert C. Byrd Green Bank Telescope, and a number of first results. These observations, prompted by our earlier detection of benzonitrile (c-C6H5CN) in TMC-1, are designed to probe the extent of hidden chemical complexity at the earliest stages of the star formation process. I will discuss the detections of new molecules in TMC-1, comment on the prospects for probing additional aromatic chemistry in this source, and examine the apparently widespread nature of benzonitrile through the early protostellar phase of star formation. These observations are being conducted in coordination with dedicated laboratory efforts to examine the formation routes of these species in the laboratory, and I will further discuss recent results concerning the formation of benzene, benzonitrile, and related molecules using chirped-pulse and cavity-enhanced microwave spectroscopy.

213.02 — Spitzer's View of the Aromatic Universe

Jan Cami[1,2]; *Els Peeters*[1,2]
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[2] SETI Institute (Mountain View, California, United States)

A significant fraction (~15%) of the carbon in the Universe resides in large, aromatic molecules that are widespread and ubiquitous in our Milky Way and other galaxies. Through their molecular properties and sheer abundance, they control the temperature of interstellar gas, and play key roles in radiative feedback processes that directly influence large-scale processes like star formation and galaxy evolution. In addition, they are driving important chemical processes as well, including H_2-formation.

Much of the aromatic carbon is in the form of polycyclic aromatic hydrocarbon species (PAHs) whose presence is revealed by a set of characteristic vibrational features in the IR. However, not a single PAH species has been reliably identified in space, and our ignorance about the identity of the cosmic PAH family hinders our progress in understanding and describing these key processes in detail. On the other hand, fullerenes (and in particular C_{60}) have been identified and detected in a variety of astrophysical environments – from the circumstellar carbon-rich surroundings of evolved stars to interstellar reflection nebulae and young stellar objects. Fullerenes share many properties with PAHs, and are also often found in environments where PAHs reside as well. Laboratory experiments as well as theoretical calculations and observational results furthermore suggest that fullerenes could well form from PAHs in these environments. Understanding the specifics of how fullerenes form, evolve and respond to their environment can thus provide important insights into astrochemistry and the characteristics of PAHs as well.

In this talk, I will provide an overview of the unprecedented, detailed view that the Spitzer Space Telescope has offered us of the environments in space where aromatics thrive and survive, and the many new questions that surfaced as a result of it. I will show how novel laboratory studies and theoretical calculations have provided breakthrough insights into the observational picture painted by the Spitzer Space Telescope regarding the interstellar physics and chemistry of PAHs and fullerenes.

213.03 — Extended Red Emission

Peter J. Sarre[1]

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Extended Red Emission (ERE) is a broad feature which is commonly observed from UV-excited interstellar grains but its origin has not been established with certainty. A full assignment and understanding of ERE would provide valuable insight into the structure and chemistry of a significant part of the dust grain population. Suggestions to date for the ERE carrier will be reviewed briefly. It is prominent in spectra of the Red Rectangle - a mixed-chemistry object which comprises a binary star HD 44179, a circumstellar disk and an extended carbon-rich bipolar nebula from which ERE is emitted. Given strong infrared emission from PAHs in the nebula, it may be suspected that aromatic carbon structures form part of the key to identifying the ERE carrier. In this study comparison between laboratory luminescence and astrophysical ERE spectra reveals that large aromatic structures which include heteroatoms have spectral characteristics which are consistent with the observed ERE feature. This proposal is supported by observation of complementary infrared bands in *ISO* and *Spitzer* spectra of ERE-emitting objects.

213.04 — Formation of Interstellar C_{60} from Silicon Carbide Circumstellar Grains

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[3] *Washington University in St. Louis (St. Louis, Missouri, United States)*

The detection of C_{60} in astronomical sources has changed our notions concerning the chemical complexity of the interstellar medium (ISM), and the repositories of gas-phase carbon. Furthermore, the $C_{60}{}^+$ cation has been proposed as a carrier of a few diffuse interstellar bands. Despite its ubiquitous presence, the mechanism of C_{60} formation remains the subject of speculation. Several mechanisms have been proposed, including destruction of polycyclic aromatic hydrocarbons (PAHs). Here we propose a new synthetic route to interstellar C_{60} from shock heating of SiC grains in the protoplanetary nebulae phase. We have conducted laboratory experiments with analog SiC grains using techniques of transmission electron microscopy (TEM) and electron energy-loss spectroscopy (EELS). The silicon carbide 3C polytype was used – the type commonly produced in the envelopes of AGB stars. We rapidly heated small SiC crystals (∼ 50 nm) under vacuum to ∼ 1300 K thermally and with ion bombardment. TEM imaging and EELS spectroscopic mapping shows that such heating leaches silicon from the silicon carbide surface, creating layered graphitic sheets. Surface defects in the crystal were found to distort the six-membered rings characteristic of graphite, creating hemispherical structures with diameters matching that of C_{60}. Such non-planar features require the formation of 5-membered rings. We have subsequently identified circumstellar grains, preserved inside primitive meteorites, that surprisingly contain a SiC core surrounded by graphite, contradicting long-standing thermodynamic predictions. The proposed mechanism readily explains the presence of C_{60} in proto-planetary (PPNe) and planetary nebulae (PNe). Subsequent injection of C_{60}, a chemically-robust molecule, into the diffuse ISM from PNe accounts for its presence in other interstellar sources.

214 — Cosmological Probes of Dark Matter III

214.01 — Probing Dark Matter Particle Properties with Ultra-High-Resolution CMB Lensing

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I will discuss a novel and powerful way to probe dark matter particle properties using deep, high-resolution cosmic microwave background (CMB) gravitational lensing measurements. These measurements can distinguish between cold dark matter and alternative dark matter models that can explain observational puzzles of small-scale structure. I will also discuss a new experiment being developed, called CMB-HD, that can achieve this science and also open new windows on the early Universe, gas and galaxy evolution, planetary studies, and the transient sky.

214.02 — Empirical measurement of the local dark matter velocity distribution and implications for direct detection

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Using two realizations of the Milky Way from the FIRE simulation, we find that the kinematics of dark matter follows closely the kinematics of accreted stars from the same mergers. We use this correspondence to obtain an empirical measurement of the local velocity distribution of dark matter by analyzing the Gaia second data release coupled with the ninth release from the Sloan Digital Sky Survey, and computing the velocity distribution of the accreted stars. We find that this velocity distribution is peaked at lower velocities than the generally assumed Maxwell Boltzmann distribution, due to the presence of a recent merger referred to as the Gaia Sausage, leading to a weakening of direct detection limits at dark matter masses less than 10 GeV. In an orthogonal study, we use Gaia DR2 to fit the local escape velocity of stars, and obtain the tail of the stellar velocity distribution that we compare to the full distribution previously found. We then study the differences between the two distributions which constrain the systematic errors on the different methods.

214.03 — Dynamical evidence for a dark substructure in the Milky Way halo

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Stars escaping globular clusters form thin, long and kinematically-cold tidal streams. In pristine conditions, these streams have nearly uniform density, however, new Gaia observations of one such structure in the Milky Way halo have revealed a likely site of perturbation. The on-sky morphology suggests a recent, close encounter with a massive and dense perturber. Known baryonic objects are unlikely perturbers based on their orbital properties, but observations permit a low-mass dark-matter subhalo as a plausible candidate. This observation opens up the possibility that detailed observations of streams could measure the mass spectrum of dark-matter substructures and even identify individual substructures and their orbits in the Milky Way halo.

214.04 — Testing Models of Dark Matter and Modifications to Gravity using Local Milky Way Observables

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Galactic rotation curves are often considered the first robust evidence for the existence of dark matter. However, even in the presence of a dark matter halo, other galactic-scale observations, such as the Baryonic Tully-Fisher Relation and the Radial Acceleration Relation, remain challenging to explain. This has motivated various models of dark matter but also long-distance, infrared (IR) modifications to gravity as an alternative to the dark matter hypothesis, as well as dark matter theories which reproduce phenomenology similar to such modified gravity scenarios. We present a framework to test a general class of such models using local Milky Way observables, including the vertical acceleration field, the rotation curve, the baryonic surface density, and the stellar disk profile. In this talk I will focus on models that predict scalar amplifications of gravity, i.e., models that increase the magnitude but do not change the direction of the gravitational acceleration. MOdified Newtonian Dynamics (MOND) as well as Superfluid dark matter are examples. We find that models of this type are in tension with observations of the Milky Way scale radius and bulge mass and that cold non-interacting dark matter provides a better fit to the data. We conclude that models that result in a MOND-like force struggle to simultaneously explain both the rotational velocity and vertical motion of nearby stars in the Milky Way. A future publication will extend this analysis to include other models such as Self Interacting Dark Matter and dark matter with large baryon scattering cross sections.

215 — Stars & Stellar Topics II

215.01 — Simulations of Stellar Winds and Exoplanet Magnetospheres: Hidden Assumptions in the Boundary Conditions

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For at least a century, the Sun has served as a useful template for our understanding of stellar atmospheres. This is especially true for the observational signatures of magnetic fields, hot coronae, and outflowing winds, all of which have been traditionally difficult to detect and characterize around other stars. Recently, the solar community has developed a number of self-consistent multidimensional simulations of the Sun's coronal heating and wind acceleration, and these models have been quite successful in reproducing a range of local measurements. These models are now being applied to other stars, with conclusions often being drawn from their output about the habitability of exoplanets circling those stars (i.e., magnetospheric plasma conditions, magnetic fields, and high-energy radiation). However, there are sometimes subtle parameters embedded in these models that have been fine-tuned for the Sun and not varied when applying them to other stars. For example, models that make use of the dissipation of MHD turbulence to power the corona rely on lower boundary conditions in the photospheric granulation. Using the Sun's granular velocity field for, say, the corona of an M dwarf would not be appropriate. Also, using the output of convection-driven wave-flux models to adjust the solar parameters to those of other stars may not be appropriate either. In the case of nearby M dwarf AU Mic, this kind of extrapolation ended up drastically underpredicting the amount of coronal heating observed in X-ray and submillimeter emission. It has been suspected that – for the coronae of cool stars with different properties than the Sun – the most important wave/turbulence modes and dissipation channels may be fundamentally different from those most important in the solar atmosphere. Thus, conclusions from solar simulation codes about extrasolar wind mass loss rates, magnetospheres, and EUV/X-ray irradiances may need to be reevaluated with more appropriate boundary conditions and coronal heating physics.

215.02 — On the Formation of Wide Binary sdB and sdO Stars

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We present a detailed analysis of the conditions required to form subdwarf stars in wide binaries via stable Roche Lobe overflow. Starting with an evolutionary grid of almost 4000 primordial binaries with component masses between approximately 1 to 8 M_{sun} and initial orbital periods of ~1 to 200 days, many of these binaries experience an Algol-like phase of evolution and a substantial fraction of those produce binaries containing subdwarfs with orbital periods of between ~20 to 500 days. We conclude that: (1) the final period is largely dependent on the assumed physics of non-conservative mass transfer; (2) the donor star (subdwarf progenitor) typically has a mass of between about 3 and 6 solar masses; (3) there is a very natural evolution of subdwarfs from a long-lived sdB stage (~100 Myr) to the sdO stage (~30 Myr); and, (4) the range of masses and effective temperatures of sdB and sdO stars can overlap substantially depending on the properties of the primordial binary. Specifically we find that the masses can range from ~0.4 to 0.8 M_{sun}, and that sdBs have temperatures in the range of $15000 < T_{eff}$ (K) < 45000 while the range for sdOs is about $25000 < T_{eff}$ (K) < 100000. One example of a post-Algol binary that is evolving towards the subdwarf stage is MWC882

(Zhou et al. 2018). The observational implications of this channel are also discussed.

215.03 — High resolution imaging of red supergiants: A long-term imaging project with the CHARA Array

Ryan P. Norris[1]; Fabien Baron[1]
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Convection plays an important role in the transport of material within many stars. In stars like the sun, the size of convection-related surface features is a small percentage of the surface radius. However, in red supergiants (RSGs), granules and convection cells are much larger. Understanding surface features on RSGs–particularly their size, contrast, and lifetime–is vital to understanding these stars in a more general sense. We present the results of a long-term study of surface features on RSG using the Michigan InfraRed Combiner (MIRC/MIRCx after 2016) at the Center for High Angular Resolution (CHARA) Array on Mt. Wilson. In the form of some the highest resolution images of any star (apart from the Sun) yet produced, we present yearly surface images spanning 2011-2012 and 2014-2016 for the star AZ Cyg and images from 2015-2016 for SU Per. We analyze the size, contrast, and lifetime of the features, providing a stringent test against 3-dimensional radiative hydrodynamics (3D RHD) models of RSGs. We also highlight future directions for research in RSG surface imaging, including the impact of optical interferometers planned for construction during the 2020-2030 decade.

215.04 — Black Hole Mass Scaling Relations

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We have performed multi-component photometric decompositions for the largest to date sample of 132 galaxies with dynamically measured supermassive black hole masses. For the 48 late-type galaxies, we have additionally measured their spiral-arm pitch angle geometries and derived dark matter halo masses via their rotational velocities. We have investigated how black hole mass ($M_{\rm BH}$) correlates with (i) bulge, (ii) disk, and (iii) galaxy stellar mass; (iv) spiral-arm pitch angle; (v) central velocity dispersion; (vi) maximum disk rotational velocity, and in turn, (vii) dark matter halo mass. Notably, we find separately for spiral galaxies (Sp) and early-type galaxies with a disk (ES/S0) and without a disk (E), that $\log(M_{\rm BH}) \propto 2\log(M_{*,bulge})$. Furthermore, the three subsamples have different $M_{\rm BH}/M_{*,bulge}$ ratios. At $M_{*,bulge} = 5 \times 10^{10} M_\odot$, $M_{\rm BH}/M_{*,bulge} = 2\%$, 1%, and 0.1%, for ES/S0, Sp, and E galaxies, respectively. Similarly, $\log(M_{\rm BH}) \propto 2\log(M_{*,galaxy})$ for early-type galaxies, while late-type galaxies exhibit a steeper relation with $\log(M_{\rm BH}) \propto 3\log(M_{*,galaxy})$. These results pose important benchmarks for formation theories and simulations, representing a significant departure from the widely adopted "linear" relation traditionally applied to all morphologies with the same $M_{\rm BH}/M_{*,bulge}$ ratio.

215.05 — Improving Binary Millisecond Pulsar Distances with Gaia

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Improved distance measurements to millisecond pulsars can enhance pulsar timing array (PTA) sensitivity to gravitational-waves, improve tests of general relativity with binary pulsars, and more. Here we report parallax-based distance measurements to six Gaia DR2 objects associated with International PTA pulsars J0437-4715, J1012+5307, J1024-0719, J1732-5049, J1910+1256, and J1843-1113. By multiplying the posteriors of the PTA distances with the Gaia distance to the companion, we improve the distance measurements, and provide a tentative detection of a previously unknown binary companion to J1843-1113.

215.06 — Depth and Mass of a Neutron Star Crust

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Neutron stars are a valuable asset to modern nuclear astrophysics in that they provide a unique environment to study matter under extreme conditions. Much of the observational data obtained from neutron stars contains information about the structure and dynamics of the crust. Using such observations to measure crust properties requires understanding the uncertainty range from models of the thickness of the different layers of the crust. These uncertainties arise from uncertainties in the properties of nuclear matter. I will use a comprehensive ensemble of nuclear matter equations of state, spanning the current uncertainty in the nuclear interaction, to examine the correlations between the crust thickness, mass distribution, and nuclear matter parameters. I will compare the results of a number of different ways to calculate the crust thickness and mass distribution, and use them to estimate the uncertainty in estimates of crust oscillation frequencies and the crust cooling time.

215.07 — The Heating and Cooling of Neutron Stars

Brianna Douglas[1]*; William Newton*[1]
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Information about the structure and evolution of neutrons stars can be obtained from modeling their thermal evolution. I will present two studies, one of the cooling the Crab pulsar, and one of the heating of accreting neutron stars as they accrete matter from a companion star. Firstly, there is some circumstantial evidence that the Crab pulsar was formed in an electron-capture supernova, which is one way stars about 8-10 solar masses die. In this type of supernova, the star's core collapses at the ONeMg stage, and produces a relatively low mass neutron star of around 1.25 solar masses. I calculate the cooling of low mass neutron stars and compare with measured upper limits on the Crab's temperature. Secondly, I consistently model the accretion of matter onto a population of neutron stars and the subsequent heating caused by nuclear reactions as the accreted matter is buried. The distribution of crustal heating as a function of initial period, magnetic field, and equation of state is presented.

215.08 — Results From the Antarctic Balloon Flight of the Hard X-ray Polarimeter X-Calibur

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X-ray polarimetry promises geometrical information about compact astrophysical objects such as accreting black holes and neutron stars that are too small to be imaged at any wavelength. While some information about the source geometry can be derived from spectral and timing measurements of the high-energy emission, results are often model dependent. X-ray polarimetry can break these degeneracies by providing two new observables, namely the Stokes parameters Q and U. X-Calibur is a balloon-borne hard X-ray polarimeter covering the 20-40keV energy range. It consists of an 8m long optical bench carrying the InFOCμS hard X-ray mirror, and a scattering polarimeter at its focal point. The optical bench is pointed with arc-second precision by the Wallops Arc-Second Pointer (WASP). The polarimeter consists of a Beryllium scattering element at the focal point of the mirror surrounded by CZT detectors on 4 sides to measure azimuthal scattering angle and energy of the scattered photons. X-Calibur was flown on a 2.5 day long stratospheric balloon flight from McMurdo (Antarctica) from Dec. 29, 2018 to Jan. 1, 2019. The observations caught the accreting X-ray pulsar GX 301-2 close to the apastron at elevated flux levels. We report here on the first X-Calibur results including the 15-60 keV light curve, the hard X-ray energy spectrum, and the first constraints on the polarization of the hard X-ray emission. We furthermore show results from simultaneous observations with the Neil Gehrels Swift and NICER X-ray telescopes. We conclude with an outlook of the physical constraints that can be derived based on future, deeper X-ray spectropolarimetric observations of X-ray pulsars.

216 — Solar Physics Division Meeting (SPD), Flares I

216.01 — Fast plasma outflows associated with impulsive microwave and hard X-ray bursts during the gradual phase of the 2017 September 10 X8.2 flare

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The 2017 September 10 X8.2 flare is a spectacular long duration event associated with a fast coronal mass ejection (CME). It features an extended gradual phase associated with hard X-ray (HXR) and microwave (MW) bursts that last for at least two hours after the flare peak (at ~1600 UT). We examine the gradual phase using multi-wavelength data recorded by the Expanded Owens Valley Solar Array (EOVSA), RHESSI, Fermi/GBM, SDO/AIA, and MLSO/K-Cor. During the extended gradual phase (~17-18 UT) when the CME already propagates to >10 solar radii, an extremely long and thin plasma sheet is visible in white light (WL) images that extends to at least ~1.5 solar radii above the solar surface. We find evidence of multitudes of fast bi-directional plasma outflows (~300-700 km/s) within the plasma sheet emanating from localized sites at very low coronal heights (0.1-0.2 solar radii above the surface), interpreted as magnetic reconnection occurring in the low corona. The occurrence of the fast plasma outflows correlates very well in time with the intermittent broadband MW emission and HXR enhancements. MW spectroscopic imaging reveals a MW source located at the looptop that coincides with a HXR looptop source. Another MW source is present in the northern leg of the flare arcade, whose temporal evolution seems to correlate with the looptop MW source but shows a time lag characteristic of the Alfvén transit time. We examine the temporal and spatial correlations among the plasma outflows, looptop MW/HXR source, and loopleg MW source, and discuss implications for magnetic energy release, plasma heating, and electron acceleration during the extended gradual phase of the flare.

216.02 — Magnetic Energy Release in Solar Flares seen through Microwave Eyes

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Solar Coronal Magnetism includes emergence of the magnetic flux from the sub-photospheric volume, evolution of the coronal magnetic field, generation and accumulation of a free non-potential magnetic energy, gradual and explosive release of this energy, generation and dissipation of turbulence. This set of phenomena drives solar flares and other forms of eruptive activity such as jets or coronal mass ejections. An emerging new remote sensing window—Microwave Imaging Spectroscopy—offers a science-transforming, entirely new look at the coronal magnetism. The foundation of this new capability is the sensitivity of the microwave emission to the magnetic field. A break-through, however, comes only when this emission is measured at many frequencies with a reasonably high spatial and temporal resolution, which is the case of a new imaging instrument—the Expanded Owens Valley Solar Array (EOVSA). In this talk we briefly present the key methodology needed to obtain the target physical parameters, show a few examples of solar flares observed with EOVSA, and discuss main physical findings made with these new data and methodology, in particular—about rapid decay of the magnetic field at the site of the primary energy release in solar flares, associated electric field and accelerated particles, plasma heating, and turbulent magnetic diffusivity. We discuss these new findings in the context of the standard model of solar flare and the contemporary ideas about the magnetic energy release, magnetic reconnection, turbulence generation, and particle acceleration.

216.03 — The Influence of Current Sheet Structure on Flare Loop Dynamics

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Solar flares are believed to result from magnetic reconnection occurring within a coronal current sheet. Flare energy is released as flux retracts through the sheet following its reconnection. This process is dictated by the magnetic field strength along the sheet through which the flux retracts. Some theoretical models, including the standard Petschek model, assume the field strength to be uniform along the sheet.

Others invoke a sheet terminating in field-free Y-points, so the field strength decreases steadily during retraction. Still others, including models of a collapsing trap, assume the field strength increases as flux retracts. Each of these assumed configurations will lead to an observably different solar flare. We study the effects of these different configurations using the thin flux tube (TFT) model of magnetic flux retraction following reconnection. This model has been shown to yield Petschek-like results when a uniform current sheet is assumed. We modify the model to study the effects of different current sheet configurations. This allows us to compare flares set in current sheets with both increasing and decreasing field strength profiles.

This work was supported by NASA's HSR program.

216.04 — Evidence for downflows in the narrow plasma sheet of 10 Sep 2017, and their significance for flare reconnection

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Current sheets are believed to form in the wakes of erupting flux ropes and to enable the magnetic reconnection responsible for an associated flare. Multi-wavelength observations of an eruption on 10 Sep 2017 show a long, linear feature widely taken as evidence of a current sheet viewed edge-on. The relation between the high-temperature, high-density plasma thus observed and any current sheet is not yet entirely clear. We estimate the magnetic field strength surrounding the sheet, and from that conclude that approximately one-third of all flux in the active region was opened by the eruption. Subsequently decreasing field strength suggests that the open flux closed down over the next several hours through reconnection at a rate $d\Phi/dt = 5 \times 10^{17}$ Mx/s. We find in AIA observations evidence of downward moving, dark structures analogous to either supra-arcade downflows more typically observed above flare arcades viewed face-on, or to supra-arcade downflowing loops, previously reported in flares viewed in this perspective. This suggests that the plasma sheet is composed of the magnetic flux retracting after being reconnected high above the arcade. We use a model of flux tube retraction following reconnection to show that this process can generate high densities and temperatures as observed in the plasma sheet. The retracting flux tubes reach their highest temperatures at the end of their retraction, well below the site of reconnection. Previous analysis of AIA and EIS data had revealed a peak in the plasma temperature very near the base of this particular sheet. This is consistent with our hypothesis that downflows descend from a higher reconnection point.

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216.05 — Structure and dynamics of the hot flaring loop-top source observed by Hinode, SDO, RHESSI, and STEREO

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We have investigated an M1.3 flare on 2014 January 13 around 21:48 UT observed at the west limb using the Hinode, SDO, RHESSI, and STEREO. Especially, the Hinode/EIS scanned the flaring loop covering the loop-top region over the limb, which is a good target to investigate the dynamics of the flaring loop with their height. Using the multi-wavelength observations from the Hinode/EIS and SDO/AIA, we found a very hot emission above the loop-top observed in Fe XXIV and 131Å channel. Measuring the intensity, Doppler velocity and line width for the flaring loop, we found that hot emission observed at the cusp-like shape of the loop-top region which shows strong redshift about 500 km s^{-1} in Doppler velocity and strong enhancement of the non-thermal velocity (line width enhancement) larger than 100 km s^{-1}. Combining with the STEREO observation, we have examined the 3D structure with loop tilt angle and have investigated the velocity distribution of the loop-top region. With the loop tilt angle, we could identify the strong redshift at the loop-top region may indicate an up-flow along the loop-top region. From RHESSI hard X-ray (HXR), and soft X-ray (SXR) emission, we found that the footpoint brightening region at the beginning of the flare has a both HXR (25-50 keV) and SXR (12-25 keV) emission in which imply that the region has non-thermal emis-

sion or accelerated particles. Then, within 10 minutes the soft X-ray (SXR) emission observed near the cusp shape region at loop top. The temporal variation of the HXR and SXR emissions and the Doppler velocity variation of the hot plasma component at the loop-top imply that the strong flow in a hot component near loop-top could be the evaporation flows which detected at the corona along the tilted loop. Moreover, The temporal evolution of the temperature observed by SDO/AIA and Hinode/EIS also shows the cooling process of the flare plasma which is consistent with the impulsively heated flare model.

216.06 — Gamma-ray emission from the impulsive phase of the 2017 September 06 X9.3 flare

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We report hard X-ray and gamma-ray observations of the impulsive phase of the SOL2017-09-06T11:55 X9.3 solar flare. We focus on a high-energy part of the spectrum, > 100 keV, and perform time resolved spectral analysis for a portion of the impulsive phase, recorded by the Konus-Wind experiment, that displayed prominent gamma-ray emission. Given a variety of possible emission components contributing to the gamma-ray emission, we employ a Bayesian inference to build the most probable fitting model. The analysis confidently revealed contributions from nuclear deexcitation lines, electron-positron annihilation line at 511 keV, and a neutron capture line at 2.223 MeV along with two components of the bremsstrahlung continuum. The revealed time evolution of the spectral components is particularly interesting. The low-energy bremsstrahlung continuum shows a soft-hard-soft pattern typical for impulsive flares, while the high-energy one shows a persistent hardening at the course of the flare. The neutron capture line emission shows an unusually short time delay relative to the nuclear deexcitation line component, which implies that the production of neutrons was significantly reduced soon after the event onset. This may be caused by a prominent softening of the accelerated proton spectrum during the flare, similar to the observed softening of the low-energy component of the accelerated electrons responsible for the low-energy bremsstrahlung continuum. We discuss possible physical scenarios, which might result in the obtained relationships between these gamma-ray components.

217 — Solar Physics Division Meeting (SPD), Photosphere/Chromsphere

217.01 — GST high-resolution observations of small-scale flux emergence in multiwavelengths

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The near-infrared imaging spectropolarimeter (NIRIS) of the 1.6 m Goode Solar Telescope (GST) at Big Bear Solar Observatory (BBSO) produces vector magnetograms at 0.24″ resolution and up to 30 s cadence. These unprecedented high spatiotemporal resolution data provide us a unique opportunity to study the small-scale magnetic flux emergence and cancellation events, which can advance our understanding of the structural evolution of photospheric fields and related dynamic activities spanning the solar atmosphere. In our previous study using NIRIS observations, we detected that during flux emergence there appears two components of magnetic fluxes, the central diffused magnetic structure with enhancing horizontal field and concentrated opposite-polarity fluxes at the two ends. In this work, we jointly analyze NIRIS and other BBSO/GST observations of NOAA AR 12665 on 2017 July 13, with the goal of shedding light on the signatures and responses of small-scale flux emergence in multiple heights. We focus on case studies of flux emergence events near the magnetic polarity inversion line. With direct imaging in broadband TiO (a proxy for continuum in photosphere at 705.7 nm) at 0.1″ resolution and 15 s cadence, we observe that magnetic flux emergence is associated with darkening of granular boundaries and elongation of granules. When newly emerged magnetic elements cancel with the existing opposite-polarity fields, bright point features are seen and they travel along the intergranular dark lanes at a speed of about 4 km/s. The canceled flux is in the order of 4×10^{16} Mx. In Hα observations (0.1 resolution and 34 s cadence) at several line positions (±1.0, ±0.6, ±0.4, and line center), we see transient brightenings in the red and blue wings, which are most probably Ellerman bombs. In a particularly well observed event, we find brightenings in Hα red-wing(0.4 Å) around the central diffused emerging region, where horizontal flux density increases and peaks at 250 Mx/cm^2; when it restores to its initial state, the horizontal flux density increases at the concentrated flux regions at the two ends. In the mean time, brightenings are also observed at concentrated flux footpoints in Hα far red-wing (0.6 Å, 1.0 Å). We suggest that these observations may reflect the reconnection process between the emerging flux and overlying field.

217.02 — On the Challenges of synthetizing solar and stellar spectra for Irradiance reconstructions

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Syntheses of solar and stellar spectra strongly depend on the adopted approximations and atomic and molecular databases. We compare LTE and NLTE syntheses of solar spectra obtained with widely used radiative transfer codes, utilizing both 3D-MHD simulations and 1D-static atmosphere models. We show that although different codes reproduce reasonably well the observed spectrum, subtle differences may translate into discrepancies of several tens of percents in the estimate of solar and stellar spectral irradiance variability.

217.03 — The formation and dissipation of current sheets and shocks due to compressive waves in a stratified atmosphere containing a magnetic null

Lucas A. Tarr[2]; Mark Linton[1]

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[2] *Physics and Astronomy, George Mason University (Fairfax, Virginia, United States)*

We study the propagation and dissipation of magnetohydrodynamic waves in a set of numerical models that each include a solar–like stratified atmosphere and a magnetic field with a null point. All simulations have the same magnetic field configuration but different heights for the model transition region, where the temperature rapidly increases from photospheric to coronal levels. Compressive wave packets introduced in the photospheric portion of the simulations refract towards the null and collapse it into a current sheet, which then undergoes reconnection. Wave mode conversion near the null generates a series of slow mode shocks localized near the null's separatrices, leading to localized current densities and heating near each separatrix. We identify the cause of the shocks and the current sheets and determine their dependence on the atmospheric and wave packet parameters. We discuss the relation between reconnection at the null, dissipation of the shocks and current sheets, and the heating of features with similar magnetic topologies, such as coronal bright points. Using current estimates of the photospheric acoustic power, we estimate that the shock and Ohmic heating we describe may account for ~1–10% of the radiative losses from X–ray and EUV bright points with similar topologies, and are similarly insufficient to account for losses from larger structures such as ephemeral regions. At the same time, the dynamics are comparable to recently proposed mechanisms for generating type–II spicules.

217.04 — ALMA detection of dark chromospheric holes

Stephen M. White[1]; Maria A. Loukitcheva[2]; Sami K. Solanki[2]

[1] *Air Force Research Laboratory (Albuquerque, New Mexico, United States)*
[2] *Max Planck Institute for Solar System Research (Goettingen, Germany)*

Atacama Large Millimeter/submillimeter Array (ALMA) observations of a quiet-Sun region at a wavelength of 3 mm are compared with available chromospheric observations in the UV and visible as well as with photospheric magnetograms. The ALMA images clearly reveal the presence of distinctive cold areas in the millimeter maps having temperatures of around 60% of the normal quiet Sun at 3 mm, which are not seen in the other data. We speculate that ALMA is sensing cool chromospheric gas, whose presence had earlier been inferred from infrared CO spectra.

217.05 — Shock heating energy in an umbra of a sunspot with integral field unit spectroscopy

Tetsu Anan[1]; Thomas A. Schad[1]; Sarah A. Jaeggli[1]; Lucas A. Tarr[2]

[1] *National Solar Observatory (Makawao, Hawaii, United States)*
[2] *George Mason University (Fairfax, Virginia, United States)*

On 2014 December 7 we used new integral field spectroscopy techniques to observe umbral flashes, which are periodic brightness increases routinely observed in the core of chromospheric lines within sunspot umbrae and are attributed to propagating

shock fronts. In this work we quantify the shock heating energy of these umbral flashes using observations in the near infrared HeI triplet obtained with the SpectroPolarimetric Imager for the Energetic Sun (SPIES), which is novel integral field unit spectrograph at the Dunn Solar Telescope. We determine the shock properties (the Mach number and the propagation speed) by fitting the measured HeI spectral profiles with a theoretical radiative transfer model using two constant property atmospheric slabs whose temperatures and macroscopic velocities are constrained by the Rankine-Hugoniot relations. From the Mach number, the shock heating energy per unit mass of plasma is derived as 2×10^{10} erg/g. We conclude that the estimated shock heating energy rate is less than the amount required to maintain the umbral chromosphere.

217.06 — Counter-streaming motions in active region magnetic arches observed by Helium I 10830Å spectroscopy

Xu Yang[1]; Wang Ya[2]; Haisheng Ji[2]; Wenda Cao[1]
[1] *Physics, New Jersey Institute of Technology (Big Bear City, California, United States)*
[2] *Purple Mountain Observatory (Nanjing, China)*

We report the first high-resolution observations of counter-streaming motions in the active region magnetic arches with Helium I 10830 Å spectroscopy, achieved by the Goode Solar Telescope at Big Bear Solar Observatory. Our observations reveal that the counter-streaming motions are due to unidirectional mass flows along alternative arches, rather than the longitudinal oscillations of filament threads as in some solar filaments. Mass flow, rooting in the magnetic network region, are pumped up from and down to the inter-granulation lanes. The apparent speed of the flow is around 15-50 km s^{-1} in the He I 10830 Å blue wing and 5-15 km s^{-1} in the red wing. Co-spatial brightenings in Atmospheric Imaging Assembly 304 Å and 171 Å images are witnessed at the same time, indicating the possible corresponding heating process. The oscillation power peaks around 4 minutes in the roots region of the arches, however, the mass flows inside the long arches seem to be continuous.

218 — Plenary Lecture: The Tools of Precision Measurements in Exoplanet Discovery and Characterization: Peeking under the Hood of the Instruments, Suvrath Mahadevan (Pennsylvania State University)

218.01 — The Tools of Precision Measurements in Exoplanet Discovery and Characterization: Peeking under the Hood of the Instruments

Suvrath Mahadevan[1]
[1] *Penn State (University Park, Pennsylvania, United States)*

Modern astronomical instruments are approaching the exquisite sensitivity to detect the signature of an Earth-mass planet around a Sun-like star. In this talk I shall discuss the challenges involved in making these difficult measurements with the Doppler radial velocity technique, and the evolution of the design of these instruments as they seek ever-tighter control of environmental parameters, higher resolution and efficiency, and to observe large spectral regions in the optical and infra-red. A suite of new technologies like frequency stabilized laser combs, low drift etalons, and deeper understanding of the detectors is enabling a new level of precision in radial velocity measurements – as well as illustrating new challenges. I will also describe how beam-shaping diffusers are now enabling space-quality photometry from the ground to aid in photometric follow-up and confirmation of transiting exoplanets.

221 — Laboratory Astrophysics Division Meeting (LAD): Bridging Laboratory and Astrophysics: Exoplanets II

221.01 — Studying exoplanet atmospheres with laboratory data

Renyu Hu[1]
[1] *Jet Propulsion Laboratory (Pasadena, California, United States)*

Observations of exoplanet atmospheres enable us to characterize their chemical composition, thermal structure, and general circulation. The observations of atmospheric transmission and emission via transit have been used to derive molecular abundances, and this method works best for high-temperature gaseous planets with H_2-dominated atmospheres. Interpreting the transit observations depends on molecular and collision-induced opacities in the relevant conditions, as well as an understanding of whether photochemical hazes like those found in the outer Solar System could form and survive the high temperatures. Meanwhile, high-resolution, line-resolving spectroscopy using large ground telescopes is a new avenue to detect molecules in exoplanet atmospheres. This method relies on molecular line lists with accurate wavelength positions. As the exoplanet field is planning future facilities and observations to characterize potentially habitable planets, new reaction rate constants, ultraviolet cross sections, and molecular spectra (e.g., CH_4line lists in the visible wavelengths and infrared spectra of biogenic gases) will be used to guide the exploration of exoplanets.

221.02 — The role of laboratory experiments and *ab initio* calculations in exoplanet atmospheric chemistry

Julianne I. Moses[1]
[1] *Space Science Institute (Seabrook, Texas, United States)*

Upcoming observations from the *James Webb Space Telescope*, *ARIEL*, and other missions and observational campaigns will enable unprecedented characterization of exoplanet atmospheric structure and composition, through transit and emission spectroscopy acquired at various phases of the planet's orbit about its host star. Theoretical models are needed to fully interpret these observations. However, such models rely on accurate laboratory and theoretical inputs that are relevant to the physical and chemical conditions of the exoplanets being observed. Many of our current inputs are based on Earth atmospheric conditions or other terrestrial and solar-system applications that have little resemblance to exoplanet atmospheric conditions. I will review recent advances in laboratory experiments and theoretical *ab initio* calculations that have improved our understanding of exoplanet atmospheric chemistry. I will also describe situations in which insufficiencies in our knowledge of kinetic reaction-rate coefficients, thermodynamic parameters, photoabsorption cross sections, microphysical and optical properties of ”exotic” hazes, and haze formation mechanisms are currently limiting our ability to accurately predict exoplanet atmospheric composition.

221.03 — The Capabilities of LUVOIR for Studies of Exoplanet Diversity

Mark S. Marley[1]*; Courtney Dressing*[2]
[1] *NASA Ames Research Center (Moffett Field, California, United States)*
[2] *UC Berkeley (Berkeley, California, United States)*

One of the great strengths of the proposed LUVOIR space observatory is that in addition to searching for potentially habitable terrestrial planets, it will find and characterize hundreds of other types of planets as well. This large population of planets will offer unparalleled opportunities for comparative planetary science over a wide range of masses, radii, and orbital separations. Direct imaging and spectroscopy with ECLIPS, an ultra-high contrast coronagraph, will enable a systematic investigation of system architectures and the diversity of exoplanet atmospheres. An investment of 424 hours with LUVOIR-A would obtain optical spectra of 30 known planets for example. For the more massive of these planets we will have previous mass measurements from Gaia or radial velocity surveys, creating a powerful data set for testing theories of planet formation, atmospheric evolution, photochemistry, and cloud processes. For newly discovered planets, astrometric observations with HDI, the telescope's high resolution imager, or ground-based radial velocity observations will constrain planet masses. LUVOIR will also offer unparalled transit science, particularly at UV wavelengths, enabling studies of photochemistry and atmospheric escape. In our poster presentation we will illustrate a few examples of LUVOIR capabilities with both the A and B architectures to explore comparative planetary science, illustrating the diversity of studies possible within a relatively modest application of observatory time.

221.04 — Direct Detection of CO in CI Tau b: Support for Hot Start Formation

This is an additional presentation of abstract 105.04. See that entry for details.

222 — WFIRST Ultra-Deep Fields I

222.01 — LSST Deep Drilling Field Program

Frederica Weiner[1]
[1] *University of Delawae (Newark, Delaware, United States)*

I will present the current plan for LSST Deep Drilling Fields (DDFs) including field selection and expected depth and cadence, as well as the recent proposals for new DDFs and DDF cadences, and describe the process and timeline for finalizing the LSST DDF plans.

222.02 — Ultra Deep Field survey with WFIRST

Anton M. Koekemoer[1]
[1] *STScI (Baltimore, Maryland, United States)*

WFIRST will enable deep field imaging across much larger areas than those previously obtained with Hubble, opening up completely new areas of parameter space for extragalactic deep fields including cosmology, supernova and galaxy evolution science. The instantaneous field of view of the Wide Field Instrument (WFI) is about 0.3 square degrees, which would for example yield an Ultra Deep Field (UDF) reaching similar depths at visible and near-infrared wavelengths to that obtained with Hubble, over an area about 100-200 times larger, for a comparable investment in time. Moreover, wider fields on scales of 10-20 square degrees could achieve depths comparable to large HST surveys at medium depths such as GOODS and CANDELS, and would enable multi-epoch supernova science that could be matched in area to LSST Deep Drilling fields or other large survey areas. Finally, achieving HUDF-quality imaging over areas 100x larger than the current Hubble Ultra Deep Field area could yield thousands of galaxies at or beyond $z \sim 8$-10, dramatically increasing the discovery potential at these earliest epochs of cosmic time.

222.03 — Co-ordinating Observations of Deep and Ultra-deep Fields Between Observatories

Peter L. Capak[1]
[1] *Caltech (South Pasadena, California, United States)*

P. Capak will give an overview of the current efforts to co-ordinate observations of Euclid, LSST, Subaru, and other observatories on potential WFIRST deep fields. He will give a list of potential locations for the deep and ultra-deep WFIRST fields and highlight the pros and cons.

222.04 — WFIRST Deep Fields and the ELTs

Alice E. Shapley[1]
[1] *UCLA (Los Angeles, California, United States)*

An Ultra-Deep Field survey with the Wide Field Infrared Survey Telescope (WFIRST) will uncover unprecedented photometric sample sizes of galaxies at $z>7$. These samples will provide important constraints on the luminosity function and large-scale structure of galaxies within the epoch of reionization. However, in order to gain a complete picture of the production and escape of ionizing radiation and the nature of the earliest stellar populations, we require spectroscopic observations of these distant galaxies in the rest-frame ultraviolet and optical. The next generation of ground-based telescopes including the Thirty Meter Telescope, Giant Magellan Telescope, and European Extremely Large Telescope will enable sensitive spectroscopic follow up of galaxy photometric candidates uncovered by a WFIRST Ultra-Deep survey. Spectroscopic measurements of key emission features such as hydrogen Lyman-α and multiple metal lines will enable essential constraints on the nature of massive stars and the interstellar medium during the epoch of reionization. I will describe the powerful synergy between a WFIRST Ultra-Deep Field Survey and ELT spectroscopic follow-up

223 — Cosmological Probes of Dark Matter IV

223.01 — What can the dark sector do?

Marc Kamionkowski[1]
[1] *Johns Hopkins University (Baltimore, Maryland, United States)*

Dark matter solves the problems for which it was introduced if it pressureless and has only gravitational interactions with itself and with ordinary matter. Likewise, dark energy interacts only gravitationally but has negative pressure. Still, both parts of the dark sector could conceivably have properties beyond these minimal requirements. Here I consider several ways the dark sector might differ from the minimal scenario, some of the observational consequences, and current and possible future constraints. Specific examples include new long-range interactions for dark matter, baryon–dark-mater interactions, and several dark-energy novelties.

223.02 — Dark Matter and Fusion

Samuel McDermott[1]
[1] *Theoretical Astrophysics, Fermi National Accelerator Laboratory (Chicago, Illinois, United States)*

Over the past several years, non-WIMP dark matter candidates have attracted a surge of interest in the particle physics community. In this two-part talk, I will summarize the underlying physics motivation for (and observable consequences of) a dark matter that is able to form a bound state of fundamental constituents. I will examine the astrophysical implications of a dark fermion that can form two-body bound states and some ongoing theoretical work to elucidate the dark sector ingredients necessary to lead to "successful" late-time fusion phenomenology.

223.03 — How sound are our (ultra-light axion) approximations?

Daniel Grin[1]; Jonathan Cookmeyer[3]; Tristan L. Smith[2]
[1] *Haverford College (Pasadena, California, United States)*
[2] *Swathmore College (Swarthmore, Pennsylvania, United States)*
[3] *UC Berkeley (Berkeley, California, United States)*

Axions are a promising dark-matter candidate. Ultra-light axions (ULAs) are motivated by string scenarios and could mitigate small-scale challenges to the ΛCDM paradigm. ULAs will be stringently tested by future cosmic microwave background (CMB) experiments and large-scale structure surveys. It is challenging to compute cosmological observables in ULA scenarios, due to the fact that the ULA field oscillates on time scales much shorter than the Hubble time. In past work, an effective fluid approximation (in which axions are modeled as a fluid with a structure-suppressing sound speed) is used to make computations feasible and obtain constraints. Here this approximation is tested against a complete solution of the ULA equations, comparing the induced error of CMB observables with the sensitivity of current and future experiments. In the most constrained mass range for a ULA dark matter component (10^{-27} eV $\leq m_a \leq 10^{-25}$ eV), the induced bias on ULA parameters from *Planck* is less than 1σ. In the cosmic-variance limit (including temperature and polarization data), the potential bias on parameters is 4-10σ at Fisher level; this implies that tests of ULAs using data from future efforts like CMB Stage-4 will require more precise methods. It is also found using the exact and effective fluid calculations that if ULAs compose all the dark matter, the suppression of power relative to standard cold dark matter scales with wave number as k^{-8}, rather than the often-used k^{-16} 'fuzzy'-dark matter scaling, with possible implications for small-scale observables.

223.04 — Probing the effective sound speed of the dark sector using the CMB

Tristan L. Smith[1]; Daniel Grin[2]; David Robinson[1]; Max Aifer[2]
[1] *Swarthmore College (Swarthmore, Pennsylvania, United States)*
[2] *Haverford College (Haverford, Pennsylvania, United States)*

The generalized dark matter framework provides tools which systematically characterize, in a data-driven way, the cosmic expansion history at range of different epochs. Using a principle component analysis (PCA) to apply this framework to the entire dark sector may yield new insight on cosmological axion fields, the Hubble tension, neutrino interactions and species, the physical properties of dark matter, and the nature of dark energy. This talk presents the first steps in developing a generalized dark sector PCA to determine the effective sound speed of the dark sector from measurements of the cosmic microwave background.

224 — Education & History

224.01 — NASA's Universe of Learning: Connecting Learners to the Subject Matter Experts of NASA Astrophysics

Emma Marcucci[1]; Brandon L. Lawton[1]; Janice C. Lee[2]; Denise A. Smith[1]; Gordon K. Squires[2]; Anya A. Biferno[3]; Kathleen Lestition[4]; Lynn R. Cominsky[5]
[1] *Space Telescope Science Institute (Baltimore, Maryland, United States)*
[2] *Caltech/IPAC (Pasadena, California, United States)*
[3] *NASA JPL (Pasadena, California, United States)*
[4] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*
[5] *Sonoma State University (Rohnert Park, California, United States)*

NASA's Universe of Learning (NASA's UoL) is a competitively-awarded program that creates resources and experiences that inspire and enable learners of all ages and backgrounds explore fundamental questions in science, experience how science is done, and discover the universe for themselves. Using its direct connection to the science and the experts behind the science, NASA's UoL creates and delivers timely and authentic resources and experiences for learners.

In this presentation, we will provide an overview of NASA's UoL and describe our efforts to involve subject matter experts (SMEs) (scientists and engineers) from across the broad range of NASA Astrophysics themes and missions in all of our projects. NASA Astrophysics SMEs are critical to the success of the program because they (1) provide a direct connection to the science, (2) ensure accuracy of content, and (3) provide learners with a personal connection to NASA science. Research and evaluation have shown that these direct connections to science are critical to enhancing learners' experiences and outcomes. We have identified, with input from the community, a range of ways SMEs can be involved in providing science expertise to NASA's UoL products and programs. Involvement can include providing science review, participating in person or remotely in events, participating in the development of resources, and more. The next step in our work is to provide a way to connect SMEs with relevant opportunities. We are leveraging existing SME database infrastructure to do just this. During the presentation, we will share the SME database and how participants can register their interest. The database will provide connections between SMEs and a menu-of-opportunities to engage learners through NASA astrophysics content and programs.

NASA's UoL is a unique partnership between the Space Telescope Science Institute, Caltech/IPAC, Jet Propulsion Laboratory, Smithsonian Astrophysical Observatory, and Sonoma State University and is supported by NASA under cooperative agreement award number NNX16AC65, as part of the NASA Science Mission Directorate Science Activation program.

224.02 — Update on the Non-profit Project to Produce and Disseminate a Free, Open-source Astro 101 Textbook and Resource Hub

Andrew Fraknoi[1]; David Morrison[2]; Sidney Wolff[3]

[1] *Fromm Institute, University of San Francisco (San Francisco, California, United States)*

[2] *NASA Ames (Mountain View, California, United States)*

[3] *NOAO (Tucson, Arizona, United States)*

OpenStax (a nonprofit organization based at Rice University) has been working with senior authors Andrew Fraknoi, David Morrison, and Sidney Wolff, and about 70 other members of the astronomical community, to produce a competitive, free, open-source Astro 101 textbook. (This is part of a national program to develop free textbooks in every main field in which students take intro classes, and thus help reduce the accelerating cost of a college education.) Approximately 500 instructors and 200,000 students are using the *Astronomy* textbook this year. It can be seen and downloaded in a variety of formats at http://openstax.org/details/astronomy. A number of ancillary resources have been produced, including a bank of over 1000 multiple-choice questions and a wide range of essay type questions. The answers are behind a fire-wall for registered adopters (but registration is also free, once instructor status is verified). In addition, an Open Education Resource Hub has been assembled for the book, where authors and adopters can share resources. Some 25 resources have already been posted, including a list of free on-line videos to go with each chapter (with links), a list of free on-line lab manuals and lab exercises at the level of the book, resources about the contributions of women to astronomy and the issues they face, an introductory manual for the free *Stellarium* planetarium software, a primer for first-time instructors, sample syllabi, etc.

224.03 — Astronomy from the Moon: Galaxy First Light Imaging, Earth Observation

Steve Durst[1]

[1] *International Lunar Observatory Association (ILOA) (Kamuela, Hawaii, United States)*

2019 Astronomy from the Moon continues to expand as a promising new frontier for astronomy in the 21st century and as an early 'light industry' for the Moon. China is pioneering with first robotic telescopes on another world with lunar near-side Lunar Ultraviolet Telescope (LUT) aboard the Chang'e-3 station and with lunar far-side Netherlands-China Low Frequency Explorer (NCLE) aboard the Chang'e-4 station – almost a half-century after USA Apollo 16 commander John Young obtained astronomical images on the lunar surface with a Far-UV spectrograph camera. Indian astrophysicists have expressed interest in lunar-based astronomy, as have astronomers in Europe, Japan, Russia, Canada, Korea, as well as developing independent enterprises such as the International Lunar Observatory Association (ILOA) based on Hawai'i.

In observing the Milky Way galactic center, ILOA chose as the first-light image for its ILO-X and ILO-1 instruments, from hundreds of Hawaii astronomer suggestions and considerations, a majestic, inspiring, directional, iconic object. The first-ever image of the Galaxy from the Moon could be as influential and inspiring as the first image of the Earth ever from the Moon: A look ahead at the human future in the 21st century out in the Galaxy, like the first look back at the heritage and fragility of spaceship Earth in the 20th.

Long-duration, high-resolution observation of Earth meteorology, magnetosphere and rotation can produce enhanced, unique and highly valuable data and information across a wide spectrum of interests and applications. From solar weather, to navigation accuracy, to commerce, aerospace, defense, as well as astrophysics and precession information needs for increasingly precise values and expressions for the Rotation of the Earth, observation from the Moon, including interferometry and VLBI, provides a new entire world for perspectives on the infinite universe.

224.04 — The Explanation for Helium Flashes and Type Ia Supernovae

Kenneth G. Gayley[1]
[1] *Univ. of Iowa (Iowa City, Iowa, United States)*

It is widely known that the onset of ion fusion in the presence of highly degenerate electrons results in nuclear runaway, and that this causes "helium flashes" and type Ia supernovae. This is of interest because our own Sun will eventually undergo a helium flash, and type Ia supernovae provide an important standard candle for cosmology. These runaway processes are well modeled, but the widely repeated conceptual explanation is physically incorrect, as can be shown from elementary gas physics. The correct explanation is just as accessible and considerably more interesting, as it exposes the remarkable quality of the energy exchange between degenerate and ideal species in thermal contact. In the process, it reveals crucial insights about the contrasting thermodynamics of degenerate versus ideal equations of state.

224.05 — Two Astronomy Demos: Milky Way "Stars like Grains of Sugar" and Phases with a Golf Ball, the Sun and the Moon

Gene G. Byrd[1]
[1] *University of Alabama - Tuscaloosa (Tuscaloosa, Alabama, United States)*

Indoor and outdoor astronomical size/distance demonstrations are well- known, e.g., the huge ratio of the Sun's size versus planets and the separations of the Sun and planets versus their sizes. Here we discuss two demos showing *not sizes* but astronomical number and shape. In the first, we have used grains of sugar to help students appreciate the immense number of Milky Way Galaxy stars. For an elementary school class, we bought a 5 lb. bag of fine-grained sugar. The size of a grain is about 0.1 mm so a 10x10x10 cm bag would be 1000x1000x1000 grains in length, width and depth.. Multiplying, our bag had about a billion grains, (about the same as the number of stars in a dwarf galaxy). I had the teacher theatrically pour the bag's grains slowly into a container letting the students see and, afterward, feel the "multitude" of sugar stars in just one bag. . But of course, there are about 100 billion stars in the disk of our Milky Way Galaxy which is comparable to the grains in a hundred bags of sugar. This is far too many to bring to class! Sand can be used if available in a conveniently shaped bag. Drawing diagrams will help students visualize the estimate.

The second demo dramatically shows the shape and origin of phases of the Moon. For this demonstration, the Sun and Moon must both be visible in a clear sky. Holding a golf or tennis ball with thumb and forefinger in the Moon's direction magically creates on a "microscopic" scale the same phase for the ball (crescent, half or gibbous) as for the much larger and more distant Moon seen "beside" the ball. The Moon and Milky Way demos provide nice photo/video ops. I acknowledge Ms. Lavender's Tuscaloosa Capitol School 4th grade and the University of Alabama College of Continuing Studies online Astronomy lab course students for serving as test subjects. See https://www.researchgate.net/profile/Gene_Byrd2 for photos etc. on this and other topics.

224.06 — No Shadow of A Doubt: Dyson, Eddington and the 1919 Eclipse Expeditions

Daniel Kennefick[1]
[1] *University of Arkansas - Fayetteville (Fayetteville, Arkansas, United States)*

This is the centenary year of the celebrated eclipse expeditions of 1919 which confirmed Einstein's theory of General Relativity. In recent decades the story of these expeditions has focused on Arthur Stanley Eddington and the question of his alleged bias in favor of Einstein's theory. It has been alleged that Eddington threw out data which did not favor Einstein's theory. Meticulous examination of the expeditions' papers reveals that this view is mistaken. The relevant data was taken by the expedition organized by the Greenwich observatory and it was the director of that observatory, the Astronomer Royal, Frank Watson Dyson, who was responsible for the decisions in question. Studies of the data analysis sheets and comparison with modern re-analysis of the original plates vindicate his decision. The story of the two expeditions,is a remarkable one and this talk will examine the people, the instruments and the science of the teams and how their work changed science forever.

224.07 — The Australian Aborigines Could Easily Discover the Variability of Betelgeuse, and They Did Discover the Variability

Bradley E. Schaefer[1]
[1] *Louisiana State Univ. (Baton Rouge, Louisiana, United States)*

Hamacher (2018) has recently put forth a popularized claim that the Australian Aborigines discovered the variability of the red supergiant Betelgeuse, as well as the variability of Aldebaran and Antares. The basis is that multiple tribal groups around Australia have long-standing lore about the red-star in what-we-now-call Orion that waxes and wanes in brightness, with this all transmitted as a morality tale. Other independent traditions are known for indicating the variability of Betelgeuse, Antares, and Aldebaran. This claimed prehistoric discovery of stellar variability runs up against various (spurious) biases within the historical communities, and there is also a healthy skeptical worry that inexperienced observers could not discover the variability. So I have made an independent assessment of the claim. I find that the claim is good, in that the Aborigines (and any other group in old times going back many thousands of years) could easily have discovered the variability. The essence is that inexperienced observers can readily note relative brightness changes down to 0.3 mag in size, while Betelgeuse (and the others) have excellent comparison stars, so Betelgeuse' variability from V=0.0 to V=1.3 is easy. Betelgeuse is one of the most prominent stars in the sky, and so will be seen often by Aborigines at night in the clear dark Outback skies. The discovery of variability would have started simply by many people at many times noting something like Betelgeuse being significantly brighter than nearby Procyon, while a few months earlier it was significantly fainter than Procyon, The Aborigines have a long proven track record of turning celestial observations into lore that gets passed along faithfully down many generations for thousands of years. This is all making the case that the Aborigines *could* discover the variability. The proof that the Aborigines *did* discover the variability is simply that they have documented lore from many tribes that unambiguously identifies the specific stars as waxing and waning.

225 — Solar Physics Division Meeting (SPD), Flares II

225.01 — The Focusing Optics X-ray Solar Imager (FOXSI)

Steven Christe[1]; Albert Y. Shih[1]; Sam Krucker[2]; Lindsay Glesener[3]; Pascal Saint-Hilaire[2]; Amir Caspi[4]; Szymon Gburek[5]; Marek Steslicki[5]; Joel C. Allred[1]; Marina Battaglia[6]; Wayne H. Baumgartner[7]; James Drake[8]; Keith Goetz[3]; Brian Grefenstette[9]; Iain Hannah[10]; Gordon D. Holman[1]; Andrew Inglis[1]; Jack Ireland[1]; James A. Klimchuk[1]; Shin-Nosuke Ishikawa[11]; Eduard Kontar[10]; Anna-maria Massone[12]; Michele Piana[12]; Brian Ramsey[7]; Richard A. Schwartz[1]; Thomas N. Woods[13]; Bin Chen[14]; Dale E. Gary[14]; Hugh S. Hudson[1]; Adam Kowalski[13]; Alexander Warmuth[17]; Stephen M. White[15]; Astrid Veronig[18]; Nicole Vilmer[16]

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[8] *Paris Observatory (Paris, France)*
[9] *Leibniz Institute for Astrophysics Potsdam (Germany, Germany)*
[10] *University of Graz (Graz, Austria)*
[11] *UC Berkeley (Berkeley, California, United States)*
[12] *UMN (Minneapolis, Minnesota, United States)*
[13] *SwRI (Boulder, Colorado, United States)*
[14] *Space Research Centre, Polish Academy of Sciences (Wroclaw, Poland)*
[15] *University of Applied Sciences Northwestern Switzerland (Windish, Switzerland)*
[16] *NASA MSFC (Huntsville, Alabama, United States)*
[17] *UMD College Park (College Park, Maryland, United States)*
[18] *Caltech (Pasadena, California, United States)*

The Focusing Optics X-ray Solar Imager (FOXSI), a SMEX mission concept in Phase A, is the first-ever solar-dedicated, direct-imaging, hard X-ray telescope. FOXSI provides a revolutionary new approach to viewing explosive magnetic-energy release on the Sun by detecting signatures of accelerated electrons and hot plasma directly in and near the energy-release sites of solar eruptive events (e.g., solar flares). FOXSI's primary science objective is to understand the mystery of how impulsive energy release leads to solar eruptions, the primary drivers of space weather at Earth, and how those eruptions are energized and evolve. FOXSI addresses three important science questions: (1) How are particles accelerated at the Sun? (2) How do solar plasmas get heated to high temperatures? (3) How does magnetic energy released on the Sun lead to flares and eruptions? These fundamental physics questions are key to our understanding of phenomena throughout the Universe from planetary magnetospheres to black hole accretion disks. FOXSI measures the energy distributions and spatial structure of accelerated electrons throughout solar eruptive events for the first time by directly focusing hard X-rays from the Sun. This naturally enables high imaging dynamic range, while previous instruments have typically been blinded by bright emission. FOXSI provides 20–100 times more sensitivity as well as 20 times faster imaging spectroscopy than previously available, probing physically relevant timescales (<1 second) never before ac-

cessible. FOXSI's launch in July 2022 is aligned with the peak of the 11-year solar cycle, enabling FOXSI to observe the many large solar eruptions that are expected to take place throughout its two-year mission.

225.02 — FOXSI-2 Solar Microflares : Multi-Instrument Differential Emission Measure Analysis

P. S. Athiray[7]; Lindsay Glesener[1]; Juliana Vievering[1]; Shin-Nosuke Ishikawa[2]; Andrew Inglis[3]; Noriyuki Narukage[4]; Daniel Ryan[5]; Juan Camilo Buitrago-Casas[6]; Steven Christe[5]; Sophie Musset[1]; Sam Krucker[6]

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The plasma temperature distribution above 5 MK during microflares is often loosely constrained due to limited high sensitivity hard X-ray measurements covering the wide range of temperatures observed. The Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket experiment performs direct imaging and spectroscopy of the Sun in hard X-rays, in the energy range 4 to 20 keV. FOXSI offers better sensitivity for temperatures above 5 MK by using direct focusing grazing incidence X-ray optics, the first of its kind for dedicated solar observations. The second FOXSI flight was launched on 2014 December 11 and observed microflares, quiescent Sun and quiescent active regions. This flight was coordinated with the X-ray Telescope (XRT) onboard Hinode and the Atmospheric Imaging Assembly (AIA) onboard SDO which offers unprecedented temperature coverage for characterizing the plasma temperature distribution. We present an overview of microflares observed during the FOXSI-2 flight with concurrent brightening observed in Extreme Ultraviolet (EUV) and soft X-rays, which indicates emission beyond 10 MK. By combining data from FOXSI-2, XRT, and AIA, we determined a well-constrained DEM for the microflares. The coordinated FOXSI-2 observations produce one of the few definitive measurements of the distribution and the amount of plasma above 5 MK in microflares.

225.03 — First detection of non-thermal emission in a NuSTAR solar microflare

Lindsay Glesener[2]; Sam Krucker[1]; Jessie McBrayer Duncan[2]; Iain Hannah[3]; Brian Grefenstette[4]; Bin Chen[5]; David M. Smith[6]; Stephen M. White[7]; Hugh S. Hudson[1]

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We report the detection of emission from a non-thermal electron distribution in a small solar microflare observed by the Nuclear Spectroscopic Telescope Array (NuSTAR). On 2017 August 21, NuSTAR observed a solar active region for approximately an hour before the region was eclipsed by the Moon. The active region emitted several small microflares of GOES class ∼A and smaller. In this work, we present spectroscopy demonstrating evidence of electron acceleration in one of these microflares (GOES class A5.7) and we compare energetic aspects of the accelerated distribution to commonly studied larger flares. The flaring plasma observed by NuSTAR, with supporting observation by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), is well accounted for by a thick-target model of accelerated electrons collisionally thermalizing within the loop, akin to the "coronal thick target" behavior occasionally observed in larger flares. Future observations of this kind will enable understanding of how flare particle acceleration changes across energy scales, and will aid the push toward the observational regime of nanoflares, which are a possible source of significant coronal heating.

225.04 — Analyzing Subsecond X-ray Pulsations to Probe Particle Acceleration in a Pair of M9.3 Class Flares

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Solar flares are large releases of magnetic energy in the solar corona. Studying small timescale (≤ 2s)

fluctuations in nonthermal X-ray flux is one possible probe of the particle acceleration mechanisms at work. By measuring these timescales and comparing them to the predicted acceleration timescales (convolved with a time-of-flight timescale) called for by various acceleration mechanisms, a test for their validity can be made. Additional analysis avenues include examining the lag between spike peaks across energy bands and the quasi-periodicity of these fluctuations. This work details the analysis of small timescale fluctuations in 2 M9.3 solar flares which occurred on July 30 and August 4, 2011. The method utilized follows the methods described in Kiplinger et al. 1983 and Qiu et al. 2012. This study aims to prove the usefulness of Fermi Gamma-ray Burst Monitor (Fermi GBM) data as a means of examining these small timescale fluctuations. Data from the Reuvan Ramaty High Energy Solar Spectroscopic Imager (RHESSI) are used to determine the spectral properties of the flare. As Fermi does not use the rotation-based imaging system that RHESSI does, time profiles do not require intensive demodulation. This study will assist in having Fermi GBM data play a greater role in high energy solar flare research moving forward.

225.05 — Temporal, Spectral and Spatial Analysis of Flaring Quasi-Periodic Pulsations

Laura A. Hayes[1]; Peter Gallagher[2]; Steven Christe[1]; Brian R. Dennis[1]

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One of the key observational features in flaring emission associated with accelerated electrons is the presence of pronounced modulations and oscillatory signatures known as quasi-periodic pulsations (QPPs). To date, the underpinning mechanisms resulting in the emission modulation remains unknown, and detailed multi-wavelength investigations of flaring QPP events are required to identify the modulation process. Here we will present a detailed temporal, spectral and spatially-resolved investigation of the X1.2 solar flare from May 15 2013 that demonstrate large modulations in its emission. During the impulsive phase, pronounced QPPs with a period of 50s are observed across multiple wavebands including hard and soft X-rays, microwave, UV, EUV - essentially across the whole flaring region. We examine the modulation amplitudes of the different emissions, and in particular focus on the hard X-ray and microwave spectral indices and on the modulation of the degree of polarization of the radio emissions. To further constrain the potential QPP mechanism, we analyse spatially resolved observations of the non-thermal pulsations using both RHESSI and Nobeyama RadioHeliograph data to probe the locations of where the QPP emission is occurring. The results are suggestive of a trap-plus-precipitation model. We will also discuss the QPP modulation in relation to the observed CME eruption. The current theories to explain the presence of QPPs in the context of this event will be presented, along with a discussion of how this type of analysis can be further utilized to probe the mechanisms for electron acceleration and plasma heating.

225.06 — Warm-Target Modeling and a Solution to The Low-energy Cut-off Problem

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Solar flare hard X-ray (HXR) spectroscopy serves as a key diagnostic of the accelerated electron spectrum. However, the standard approach using the collisional cold thick-target model poorly constrains the lower-energy part of the accelerated electron spectrum, hence the overall energetics of the accelerated electrons and consequently the flare energetics are typically constrained only to within one or two orders of magnitude. I will discuss the development and application of a physically self-consistent, warm-target approach that involves the use of both HXR spectroscopy and imaging data. The approach allows an accurate determination of the electron distribution low-energy cutoff, and hence the electron acceleration rate and the contribution of accelerated electrons to the total energy released, by constraining the coronal plasma parameters. Using a solar flare observed in X-rays by RHESSI, we demonstrate that using the standard cold-target methodology, the low-energy cutoff (hence the energy content in electrons) is essentially undetermined. However, the warm-target methodology can determine the low-energy electron cutoff with $\sim$7% uncertainty at the 3σ level, hence it permits an accurate quantitative study of the importance of accelerated electrons in solar flare energetics.

226 — Solar Physics Division Meeting (SPD), DKIST I

226.01 — Status of the Daniel K. Inouye Solar Telescope

Thomas R. Rimmele[1]

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The construction of the 4m Daniel K. Inouye Solar Telescope (DKIST) on Haleakala, Maui is in its final phase. The construction of the facility is 90% complete. Operations are scheduled to begin in 2020. DKIST was designed to meet the needs of critical high resolution and high sensitivity spectral and polarimetric observations of the sun. The design allows DKIST to operate as a coronagraph at infrared wavelengths where the sky background is low and bright coronal emission lines are available. Taking advantage of its large aperture and infrared polarimeters DKIST will be capable to routinely measure the currently illusive coronal magnetic fields. The state-of-the-art adaptive optics system provides diffraction limited imaging and the ability to resolve features approximately 20 km on the Sun. Five first light instruments will be available at the start of operations. The data from these instruments will be distributed to the community via the NSO/DKIST data center located in Boulder. We will discuss the project status.

226.02 — Photospheric Flows & DKIST: Resolving Both Smaller Scales And Open Questions

Brian Welsch[1]

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The technical aim of DKIST is to resolve dynamics on spatial scales not yet observed — an achievement that also promises to resolve many important science questions. For instance, the characteristics of photospheric velocity fields on currently unresolved scales — such as the strength of vorticity present, and the lifetimes of flow patterns — have substantial implications for theories chromospheric and coronal heating. Parker long ago hypothesized that the braiding of flux tubes by photospheric flows might play a role in the generation of current sheets above the photosphere, whose dissipation should lead to atmospheric heating. More recently, van Ballegooijen and collaborators have proposed that photospheric flows evolving on time scales shorter than the round-trip, photosphere-to-transition-region travel time for Alfven waves could lead to counter-propagating waves that should induce turbulence and subsequent dissipative heating. Using methods like local correlation tracking (LCT) and feature tracking to infer flows in rapid-cadence, high-resolution DKIST observations of magnetized regions of the lower solar atmosphere should enable testing these, and other, coronal heating models.

226.03 — Filament Magnetic Fields at the DST and DKIST

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Observations from the 0.8-m Dunn Solar Telescope (DST) are qualitatively similar to data that will be produced by the 4-m Daniel K. Inouye Solar Telescope (DKIST), albeit at a lower spatial resolution and polarimetric sensitivity. We present HAZEL inversions of spectropolarimetric observations of a quiescent filament acquired with the Facility Infrared Spectropolarimeter at the DST. This study includes three observations of the He I triplet at 10830 Å on May 29 and 30, 2017. The filament was stable on May 29, and was observed in the process of rising at speeds of 20-30 km/s during the two spatial maps taken on May 30. Vector magnetic fields along the filament were obtained that show an inverse configuration indicative of a flux rope topology, including co-aligned threads. To take advantage of the better spatial and temporal resolution of the DKIST, future collaborations of the DKIST and the DST to study solar filaments are discussed. We propose to further study the evolution of solar filaments that erupt and lead to Coronal Mass Ejections using interspaced observations from the DKIST and DST spectropolarimeters. While the DST observations will give information about the global evolution of physical properties leading to the destabilization, the DKIST observations will provide the information about the physical conditions in the small-scale structures that support the filament material.

226.04 — Labeling Known Unknowns in the Chromosphere Through Forward Modeling

Donald James Schmit[1]

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Spectroscopy provides one of the basic diagnostic means of deriving the thermodynamic properties of astrophysical plasmas. Chromospheric spectral lines of cool stars like the Sun are an unique diagnostic challenge: they are optically thick and formed under non-LTE conditions. In this work, we study chromospheric line formation using a forward modeling approach. We use the Bifrost stellar atmosphere simulation to generate 340000 profiles pairs in two related transitions: Ca II 8542A and Mg II 2803A. This synthetic dataset is a powerful tool because we know both the properties of the emitting plasma (the unknown in remote sensing) and the emergent profile (the observable). We use this dataset to address two questions: 1) Which kinds of profiles occur most commonly in the simulation? 2) How much information overlap exists between the 8542A and 2803A profiles? Our research into the first question suggests that a substantial degree of degeneracy exists for chromospheric profiles: a wide range of atmospheres can generate similar profiles in a 2D or 3D hydrodynamic system. If a single profile does not provide a satisfactorily narrow distribution of atmospheric properties then a logical progression is to use more than one line. We use Bayes theorem to address to what degree the more broadly-affected 2803A spectral profile can predict the spectral profile of the 8542A line. While the wings of 8542A are predicted with high efficacy from a sample Mg II profile, we find the Doppler shifts in the line core and line core emission are not predictable by our direct use of Bayes theorem. This implies that multiple chromospheric lines, even if they ”form” in similar regions, do contain non-redundant information. Our results suggest that multi-instrument datasets and the application of machine learning techniques hold promise to advance our understanding of the chromosphere.

226.05 — Mimicking spectropolarimetric inversion using convolutional neural networks

Ivan Milic[1]; *Ricardo Gafeira*[2]
[1] *CU Boulder / LASP (Boulder, Colorado, United States)*
[2] *Instituto Astrofisica de Andalucia (Granada, Spain)*

State of the art approach for the interpretation of spectropolarimetric observations of the solar atmosphere are the so called spectropolarimetric inversions. These methods fit a model atmosphere to the observed polarized spectrum and provide us with the maximum-likelyhood solution for the parameters of the underlying atmosphere. Inversions are extremely numerically demanding, because they fully take into account all the physical processes involved in the spectral line formation. This is especially pronounced in the case of spectral lines formed in the solar chromosphere. With the advent of next generation telescopes, such as DKIST, standard, minimization-based, inversions will simply be too slow. In this contribution we propose a way to accelerate the inversions by means of convolutional neural networks. We invert a small sub-set of the data using standard inversion approach and then train a convolutional neural network to generalize the results to the full data set. We analyze this method on different synthetic and observed data sets and compare the results with the results obtained by applying standard inversion methods. We find that, given an extensive enough data set, convolutional neural networks provide results that are very close to the ones obtained by standard inversion methods, in a fraction of time.

226.06 — Magnetic reconnection in the low atmosphere: Ellerman bombs and UV bursts

Peter R. Young[1]
[1] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

Ellerman bombs (EBs) were first discovered over a hundred years ago and are widely interpreted as magnetic reconnection events occurring deep in the atmosphere. UV bursts have been actively studied since the launch of IRIS in 2013 and show many similarities to EBs, but significantly give a strong signature in the Si IV emission lines that indicate hotter temperatures. The interpretation is again magnetic reconnection, but in a higher layer of the atmosphere or with a different magnetic geometry.

The expected small spatial scales of magnetic reconnection, and the tantalizing hints from recent high resolution ground observations suggest that EBs and UV bursts will be an ideal demonstration of DKIST's capabilities. This talk summarizes recent results on EBs and UV bursts and identifies key observational capabilities of DKIST.

227 — Plenary Lecture: TBD, Elisabeth Mills (Brandeis University)

227.01 — Journey to the Center of the Galaxy: Following the Gas to Understand the Past and Future Activity of Galaxy Nuclei

Elisabeth A. Mills[1]
[1] *Brandeis University (Waltham, Massachusetts, United States)*

Centers of galaxies are some of the most extreme objects in our universe: hosting starbursts and active supermassive black holes that can launch jets and winds far outside the compact galaxy nucleus. The effects of the unique interactions between stars, gas, and black holes that occur here don't just stay confined to these small regions: they have an outsized influence on the overall evolution of galaxies as a whole. At just 8.1 kpc away, the center of the Milky way is unparalleled in its proximity, making it the best laboratory for detailed studies of the processes that govern and define galaxy nuclei. However, the Galactic center also presents a big challenge for these studies: it is a relatively quiet environment. Few stars are forming in this region, and the black hole is not active. Clearly, it hasn't always been this way: from the Fermi Bubbles to hundred-year old echoes of X-ray bursts there are many relics of an active past in the center of our own Milky Way. We also know our Galaxy center likely won't stay quiet for long: it contains a sizable reservoir of molecular gas that is the fuel for future star formation and black hole accretion. In this talk I will present the results of research following the gas and its properties from kiloparsec to sub-parsec scales to understand why the Galactic center is so quiet right now and what the future holds. Finally, I will discuss ongoing work to double and triple the sample size of galaxy nuclei with sub-parsec scale gas measurements, and what this means for putting the Galactic center in context with its more active neighbors.

228 — iPoster Plus VIII: Supernovae, AGN & Galaxies

228.01 — Galaxy Morphology Network (GaMorNet): A Convolutional Neural Network to study morphology and quenching in ∼100,000 SDSS & ∼20,000 CANDELS galaxies

Aritra Ghosh[1]; *C. Megan Urry*[1]; *Zhengdong Wang*[1]; *Kevin Schawinski*[2]; *Dennis Turp*[2]; *Meredith Powell*[1]
[1] *Yale University (New Haven, Connecticut, United States)*
[2] *Modulos AG (Zurich, Switzerland)*

We examine morphology-separated colour-mass diagrams to study the quenching of star formation in ∼100,000 SDSS (z∼0) & ∼20,000 CANDELS (z∼1) galaxies. To classify galaxies morphologically, we developed Galaxy Morphology Network (GaMorNet), a convolutional neural network that can classify galaxies according to their bulge-to-total ratio. GaMorNet does not need a large training set of real data and can be applied across multiple data-sets to do morphological classification. GaMorNet's source code as well as the trained models are made public as part of this work. We first trained GaMorNet on simulations of galaxies with a bulge and a disk component and then transfer learned using ∼25% of each data set to achieve net accuracies > 91%. The misclassified sample of galaxies is dominated by small galaxies with low S/N ratios. We find that both samples of bulge- and disk-dominated galaxies have distinct colour mass diagrams in agreement with previous studies. For both samples, a) disk-dominated galaxies peak in the blue cloud with a slowly declining tail that extends through the green valley to the red sequence and is consistent with slow exhaustion of gas with no rapid quenching; b) bulge-dominated galaxies clearly show a dip in the green valley while peaking in the red sequence suggesting rapid quenching and fast evolution across the green valley.

228.02 — (withdrawn)

This abstract was withdrawn.

228.03 — New Content and Functionality in NED: Summer 2019 Update

Joseph M. Mazzarella[1]; *Xiuqin Wu*[1]; *Barry F. Madore*[1]; *George Helou*[1]; *Marion Schmitz*[1]; *David O. Cook*[1]; *Xi Chen*[1]; *Rick Ebert*[1]; *Jeffery D. Jacobson*[1]; *Scott Terek*[1]; *Tak M. Lo*[1]; *Hiu Pan Chan*[1]; *Olga Pevunova*[1]; *Cren Frayer*[1]
[1] *Caltech (Pasadena, California, United States)*

The NASA/IPAC Extragalactic Database (NED) is undergoing a major expansion in data content and functionality improvements. A fusion of attributes for prior objects in the system with fundamental measurements from NASA's GALEX, 2MASS and ALLWISE sky surveys, as well as source catalogs from the Spitzer, Hubble and Chandra Space Telescopes and data joined from over 114,000 journal articles, is vastly increasing the opportunities for mul-

tiwavelength research and discoveries. We will review highlights of recent additions to the database, demonstrate capabilities of the new user interface, and summarize current plans for the future that are being refined with further input from the community to prepare for the 2020s. NED is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration.

228.04 — AGN Feedback from Precessing Jets on the Turbulent Intracluster Medium

Yinghe Lu[1]*; Paul M. Ricker*[1]
[1] *University of Illinois, Urbana-Champaign (Urbana, Illinois, United States)*

To study feedback from active galactic nuclei (AGNs) in hydrodynamical simulations of isolated galaxy cluster environments, we have developed a new sink particle model for supermassive black hole (SMBH) accretion and jet launching. Using the new model, we have run simulations of the cores of clusters with the hydrodynamic code FLASH. We compare our jets to numerical simulations of accretion disks and jets in regions close to SMBHs and investigate the convergence of our model. We also study the interaction of precessing AGN jets, driven turbulence, and radiative cooling, aiming to determine the amount of turbulence produced by jet feedback and whether it can help regulate accretion. The results are important for addressing the question of how AGN jets deposit energy into the intracluster medium in a distributed manner.

229 — iPoster Plus X: Instrumentation Space, Ground and Computation

229.01 — Overview of the science capabilities of the Canada-France-Hawaii Telescope.

Daniel Devost[1]
[1] *Canada-France-Hawaii Telescope (Kamuela, Hawaii, United States)*

I will give a quick overview of the science capabilities of the suite of instruments available at the Canada-France-Hawaii Telescope. The telescope capabalities go from UV wide field imaging to NIR high resolution spectropolarimetry and velocimetry. Twenty nights are available on five instruments for observations in Queue Scheduled Observing mode every semester.

Our one square degree imager and most productive instrument, MegaCam, can deliver exquise image quality in the u′ band with unprecedented sensitivity. It is also equiped with an ultrawide gri filter that can be used for asteroid detection. The camera also offers a suite of state of the art filters that records high quality images with broad band g′, r′, i′ and z′ filters and narrow band Hα, Hα-off, [O III], [O III]-off and CaHK filters. All together, the science that can be done with the camera is quite broad, ranging from the study of low metallicity stars in the Milky Way to the study of dark matter and dark energy at high redshift using gravitational lensing and supernovae. SITELLE, a Fourier Transform Imaging Spectrograph and ESPaDOnS, an R70k spectropolarimeter complete our suite of optical instrumentation. SITELLE can observe up to 4 million spectra simultaneously over a 11′ FOV at a resolution ranging from 2 to 9000. This very powerful and novel instrument is most useful for the study of extended emission line objects in the Galaxy or at higher redshift. On the other hand, ESPaDOnS can derive magnetic fields, metal content and even find exoplanets around local stars. In the NIR, CFHT offers two instruments, WIRCam, a 20′ FOV camera and SPIRou, a newly commissioned NIR R65k resolution high precision velocimeter and spectropolarimeter. Both instrument observe from Y to K and have the capability to find and characterise exoplanets.

230 — iPoster Plus XII: Cosmology

230.01 — Estimating Astrometric Anomalies and Redshift with Evolutionary Physical Constants

Rajendra P. Gupta[1]
[1] *Macronix Research Corporation (Ottawa, Ontario, Canada)*

We have developed a cosmological model by allowing the speed of light c, gravitational constant G and cosmological constant Λ in the Einstein filed equation to vary in time, and solved them for Robertson-Walker metric. Assuming the universe is flat and matter dominant at present, we obtain a simple model that can fit the supernovae 1a data with a single parameter almost as well as the standard ΛCDM model with two parameters, and has the predictive capability superior to the latter. The model, together with the null results for the variation of G from the analysis of lunar laser ranging data determines that at the current time G and c both *increase* as $dG/dt = 5.4GH_0$ and $dc/dt = 1.8cH_0$ with H_0 as the Hubble constant, and Λ *decreases* as $d\Lambda/dt = -1.2\Lambda H_0$.

This variation of G and c is all what is needed to account for the Pioneer anomaly, the anomalous secular increase of the Moon eccentricity, and the anomalous secular increase of the astronomical unit. We also show that the Planck's constant h *increases* as $dh/dt = 1.8hH_0$ and the ratio D of any Hubble unit to the corresponding Planck units *increases* as $dD/dt = 1.5DH_0$. We have shown that it is essential to consider the variation of all the physical constants that may be involved directly or indirectly in a measurement rather than only the one whose variation is being considered. With this approach we will present the current status of our work on how universe may have evolved from zero rather than from infinity (i.e. singularity) and on the formation of large structures – galaxies, clusters, and superclusters.

300 — Plenary Lecture: Transiting Exoplanets: Past, Present, & Future, Joshua Winn (Princeton University)

300.01 — Transiting Exoplanets: Past, Present, & Future

Joshua N. Winn[1]
[1] *Princeton University (Cambridge, Massachusetts, United States)*

NASA's Kepler and K2 missions made major advances in exoplanetary science, by detecting thousands of transiting planets with a level of photometric precision only possible with space-based observations. These missions revealed strange and unanticipated planetary systems, while also finding planets that resemble the Earth in key respects. However, the Kepler telescope only monitored 5% of the celestial sphere, leaving most of the nearest and brightest stars unexplored. The Transiting Exoplanet Survey Satellite (TESS) takes the next logical step by performing a nearly all-sky survey. The survey began in July 2018. At this point, more than 500 planet candidates have been identified, and are being confirmed through a world-wide effort with ground-based telescopes. More generally, TESS explores the bright and variable sky, including comets and asteroids, stellar flares and pulsations, novae and supernovae.

301 — Instrumentation: Space Missions Poster Session

301.01 — A Modified Kirkpatrick-Baez Design for a Practical Astronomical X-ray Telescope

Dana Longcope[1]*; Loren W. Acton*[1]*; Charles Kankelborg*[1]
[1] *Montana State Univ. (Bozeman, Montana, United States)*

Kirkpatrick-Baez (K-B) optics offer a means of imaging soft x-rays with modest resolution and a multi-arc-minute field of view at a cost far below the conventional Wolter design. Such a low-cost system could be useful for dedicated, long time-line observation of astronomical x-ray sources from orbit. A K-B telescope consists of crossed arrays of parabolic mirrors at grazing incidence. The classic K-B design is subject to significant aberration, arising from interplay between the focusing of the fore and aft mirror arrays. We demonstrate here a modified K-B design with aberrations reduced by an order of magnitude. We show, furthermore, that it is possible to construct such a system by constraining flat "slats" of commercially-available glass in precision machined grooves. The slats deform into shapes which adequately approximate the optimal figures, thereby yielding focusing better than the best version of the classic K-B design. The result is a new approach that greatly simplifies the task of achieving both useful resolution and high effective area for x-ray astronomy applications.

301.02 — Characterization of Carbon Nanotubes for use as Field Emission Sources on MiniEPMA

Collin Flynn[1,2]
[1] *Physics, Coe College (Racine, Wisconsin, United States)*
[2] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

Aerospace technology has constantly moved towards efficiency and miniaturization. Efficiency is particularly important for deep space missions, where sunlight is lacking. The Mini Electron Probe Micro Analyzer (MiniEPMA) is a highly efficient flight concept capable of spatially mapping the elemental composition of a mineral target on an airless body (e.g. a comet, asteroid, or moon). The MiniEPMA's efficiency is largely due to its use of carbon nanotubes (CNTs), which are extremely efficient at generating electrons compared to other materials commonly used as field emission sources, such as lanthanum hexaboride (LaB_6) and tungsten filaments. The instrument uses a 10 by 10 addressable array of CNT pillars approximately 100 μm in diameter. However, not all CNT arrays are alike. We have found very different field emission capabilities among CNT arrays that underwent different growth conditions, such as catalyst type, catalyst thickness, and the time and gas concentration used during the growth. The effects of the growth conditions on field emission were studied with a focus on performance and longevity, as well as uniformity within the array.

301.03 — HaloSat: The Case of the Missing Baryons

Rebecca Ringuette[1]
[1] *Physics and Astronomy, University of Iowa (Iowa City, Iowa, United States)*

Baryonic matter provides the substance of all the matter in the universe that is familiar, including people, planets, and protons. However, current calculations indicate about one-third of the baryons in the universe to be missing. One possible place baryons can 'hide' from detectors is in the hot halos surrounding galaxies. As the closest galaxy available, the Milky Way Galaxy provides the best halo for study of diffuse x-ray emission. Currently orbiting, HaloSat is the first CubeSat funded by NASA to accomplish an astrophysical mission: determine whether there is a significant presence of baryonic matter in galactic halos in light of the missing baryon problem. At a temperature of about 10^6 K, the hot halo of the Galaxy provides strong emission lines from O-VII and O-VIII at 561 eV and 653 eV. We adapted off-the-shelf low energy x-ray instrumentation to the low-cost format of a CubeSat with additional modifications to fulfill our mission goals. Recently, HaloSat accomplished full design sensitivity for the measurement of the oxygen lines in the halo and continues to collect data. The in-flight calibration of the instrument will also be discussed, along with background cuts and subtraction methods.

301.04 — MISC — An Exoplanet Transit Spectrometer for the Origins Space Telescope

Thomas L. Roellig[1]; *Itsuki Sakon*[2]; *Kimberly Ennico*[1]; *Taro Matsuo*[3]; *Tomoyasu Yamamuro*[4]; *Yuji Ikeda*[5]
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The Origins Space Telescope (OST) is one of four potential flagship missions that have been funded by NASA for study for consideration in the upcoming Astrophysics Decadal Review expected in 2020. In order to fit inside the NASA cost guidelines, a OST Baseline Mission Concept has been developed that consists of a 5.9m diameter telescope that is cooled to 4.5K and a mission that will be optimized for efficient mid and far-infrared astronomical observations. An initial suite of three focal plane instruments was chosen for the Baseline version of this observatory. The Mid-Infrared Transit Spectrometer (MISC) instrument will observe at the shortest wavelengths of any of these instruments, ranging from 2.8 to 20 microns and is optimized for measurements of bio-signatures in the atmospheres of transiting exoplanets. This wavelength range allows measurements of the surface temperatures of the exoplanets as well as detections of the bio-signature molecules O_3, CH_4, H_2O, CO_2, and N_2O at Earth-levels, should they exist in an exoplanet atmosphere. A dichroic beam-splitter picks off 2.0-2.8 micron light from the host star and sends it to a small detector array that is used to provide fine pointing correction signals to a tip-tilt mirror in the telescope optics. The MISC instrument has a densified pupil spectrometer design with R$\sim$50-300 and is capable of exoplanet transit and emission spectroscopy with spectro-photometric stability as low as 5 ppm. This allows at least 3.6-σ detections of all the lines of interest in 85 transits of a K=9.8 magnitude M-star. This presentation covers the design and expected performance of this instrument when observing exoplanet transits of M stars.

301.05 — Updates on the Performance and Calibration of HST/STIS

S. Tony Sohn[1]; *Doug Branton*[1]; *Joleen K. Carlberg*[1]; *John H. Debes*[1]; *Susana E. Deustua*[1]; *Sean A. Lockwood*[1]; *Matthew Maclay*[1]; *TalaWanda R. Monroe*[1]; *Charles R. Proffitt*[1]; *Allyssa Riley*[1]; *Daniel Welty*[1]
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The Space Telescope Imaging Spectroscope (STIS) has been on board the Hubble Space Telescope (HST) for over 20 years and continues to produce high quality data. The instrument's diverse capabilities include spatially resolved spectroscopy in the UV and optical, high spectral resolution echelle spectroscopy in the UV, and solar-blind imaging in the UV. STIS also supports unique visible-light coronagraphic modes that keep the instrument at the forefront of exoplanet and debris-disk research. The instrument's characteristics evolve over time, and the STIS branch at the Space Telescope Science Institute (STScI) monitor its performance and continually work to optimize its data products. In this contribution, we present updates on: (1) the performance of the STIS CCD and FUV & NUV MAMA detectors; (2) the calibrated science products delivered by CalSTIS; (3) the STIS Data Handbook; (4) the calibration of the spectral sensitivity, including a program to derive a new sensitivity curve for E140M; and (5) other recent user-relevant issues.

301.06 — Seventeen Years of the Hubble Space Telescope's Advanced Camera for Surveys: Calibration Update

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The Advanced Camera for Surveys (ACS) has been a workhorse Hubble Space Telescope (HST) imager for over seventeen years, subsequent to its Servicing Mission 3B installation in 2002. The once defunct ACS Wide Field Channel (WFC) has now been operating over twice as long (>10yrs) 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.

We present results from long-term monitoring of WFC dark current and readout noise, results from new studies of detector performance for both WFC and the ACS Solar Blind Channel (SBC), and updated ACS software tools for the user community. Highlights include: 1) a WFC readout simulator tool that accurately reproduces the effects of degraded WFC charge transfer effeciency (CTE); 2) color-dependent aperture corrections for SBC point-source photometry; and 3) a refined WFC geometric distortion solution, exploiting precise astrometry of the ACS astrometric calibration field (globular cluster 47 Tucanae) provided by GAIA DR2.

301.07 — Calibration of the HST ACS/WFC Linear Polarization Filters

Tyler D. Desjardins[1]
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We present the calibration of the Hubble Space Telescope (HST) linear polarization filters for the Advanced Camera for Surveys Wide Field Channel (ACS/WFC). Using observations of the bright (V∼11.7 mag), unpolarized white dwarf G191-B2B and a polarized standard GSC 08169-01120 (V∼13.4 mag), we re-estimate the coefficients required for transforming ACS/WFC images using the POLV0, POLV60, and POLV120 filters into Stokes I, Q, and U images, along with extracting the polarization fraction and angle. We further discuss the science use-cases for the ACS polarization filters in the era of joint HST and James Webb Space Telescope observations.

301.08 — Trace and Wavelength Calibrations of the HST/ACS G800L Grism

Nimish P. Hathi[1]*; Norbert Pirzkal*[1]*; Norman A. Grogin*[1]*; Marco Chiaberge*[1]
[1] *STScI (Baltimore, Maryland, United States)*

The HST/ACS G800L grism, an optical slitless spectroscopy mode on ACS, has been very stable since its inception in 2002, but no major effort to improve its trace and wavelength calibrations has been attempted since 2005. The accurate calibration of the spectral trace and the dispersion solution are crucial to locate the spectrum in the grism image as well as to precisely identify spectral features in a spectrum. We obtained new observations of an emission line Wolf-Rayet star (WR96) in the HST Cycle 25 (PID: 15401) to undertake a thorough analysis of verifying and improving the ACS grism calibrations. To account for the field dependence, we observed WR96 at 3 different observing positions over the ACS field of view, but that is inadequate coverage to properly sample the entire ACS field of view. To account for that, we are uniformly reprocessing all the archival ACS grism data of WR96. By combining all of the available data we can now derive a more finely sampled field dependence of the grism dispersion solutions. These data, combined with a new approach to solving for the polynomial coeffcients of the field dependence of both the trace and wavelength calibrations, allow us to improve the accuracy of the grism calibration. We will present the latest results from this analysis.

301.09 — Assessing the Accuracy of Relative Photometry on Saturated Sources with ACS/WFC

Melanie Kae Batara Olaes[1]
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Upon full-well saturation, the pixels on the ACS/WFC CCDs will bleed excess charge onto adjacent pixels along their column. For these saturated sources, aperture photometry may report a lower flux than expected. However, this affect can be mitigated by defining an extraction aperture which encompasses all of the pixels which contain the full-well bleed. Here we present a functional assessment of relative photometry of saturated sources from observations of globular cluster 47 Tuc. Given a successful identification of pixels which contain the lost flux, we demonstrate an alternate method of aperture photometry where >90% accurate photometry of saturated stars can still be obtained out to 2 magnitudes brighter than the standard method.

301.10 — Focus-Diverse, Empirical PSF models for the Hubble Space Telescope ACS/WFC

Andrea Bellini[1]; Jay Anderson[1]; Norman A. Grogin[1]; Nathan Miles[1]
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Accurate Point-Spread Function (PSF) models are critical in a large variety of science investigations, from stellar photometry and astrometry to galaxy deconvolution. Focus variations, primarily due to uneven Sun and Earth heating of the Hubble Space Telescope but also to outgassing of the metering truss, have a significant impact on the shape of the ACS/WFC PSFs. These variations have been largely overlooked since the installment of the ACS in 2002. Now that thousands of images have been collected by the ACS/WFC over the past 17 years in many filters, we can analyze them in a self-consistent way and derive focus-diverse, empirical PSF models that we show to be superior to any prior library PSF models. These new PSF models will be soon made publicly available to the astronomical community through easy-to-use Python tools within the STScI astropy/photutils package.

301.11 — The Search for Biosignatures and Exo-Earths with the LUVOIR Mission Concept

Giada Arney[1]
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The Large Ultra Violet-Optical-Infrared (LUVOIR) Surveyor is one of four mission concepts being studied by NASA in preparation for the 2020 Astrophysics Decadal Survey. LUVOIR is a general-purpose space-based observatory with a large aperture (8-15 m) and a total bandpass spanning from the far-UV to the near-infrared. One of LUVOIR's main science objectives is to directly image temperate Earth-sized planets in the habitable zones of Sun-like stars, measure their spectra, analyze the chemistry of their atmospheres, and obtain information about their surfaces. LUVOIR can also observing potentially habitable exoplanets transiting nearby M dwarf stars. Such observations will allow us to evaluate these worlds' habitability and search for the presence of remotely detectable signs of life known as "biosignatures." We will discuss the strategies for Exo-Earth detection and characterization, including specific observational requirements for astrobiological assessments of exoplanetary environments with LUVOIR. The survey of the atmospheric composition of dozens of potentially habitable worlds would bring about a revolution in our understanding of planetary formation and evolution, and may usher in a new era of comparative astrobiology.

301.12 — The Capabilities of LUVOIR for Studies of Exoplanet Diversity

This is an additional presentation of abstract 221.03. See that entry for details.

301.13 — Overview of the LUVOIR Space Observatory Concepts

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[3] *Ohio State University (Columbus, Ohio, United States)*

The Large UV/Optical/IR Surveyor (LUVOIR) is a concept for a highly capable, multi-wavelength space observatory with ambitious science goals. This mission would enable great leaps forward in a broad range of science, from the epoch of reionization, through galaxy formation and evolution, star and planet formation, to solar system remote sensing. LUVOIR also has the major goal of characterizing a wide range of exoplanets, including those that might be habitable – or even inhabited. But perhaps LUVOIR's most important scientific capability is its ability to address the science questions of the 2040s and beyond that scientists have not yet thought to ask.

Here we provide a high-level overview of the current LUVOIR observatory architectures. Two variants are being designed in preparation for the Astro2020 Decadal Survey. LUVOIR-A features a 15-m diameter on-axis primary mirror and LUVOIR-B has an 8-m off-axis primary mirror. Four candidate instruments are being studied: 1) A NUV to NIR high-performance coronagraph (ECLIPS), 2) a wide-field NUV to NIR imaging camera (HDI), 3) a FUV to optical multi-resolution, multi-object spectrograph (LUMOS), and 4) a high-resolution UV spectropolarimeter (POLLUX). LUVOIR covers a total bandpass of 100 nm to 2500 nm and was designed to be serviceable and upgradable. We envision LUVOIR as a community-driven observatory, providing cutting-edge scientific capabilities over a long mission lifetime.

301.14 — Observing the Solar System with LUVOIR: high angular resolution with a segmented aperture

Shawn Domagal-Goldman[1]; Roser Juanola-Parramon[1,2]; Giada Arney[1]; Aki Roberge[1]

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LUVOIR (Large UV Optical Infrared telescope) is a concept for a large multi-wavelength observatory, which would enable transformative advances across a broad range of astrophysics. With a proposed launch date in the mid 2030s two architectures are being studied: LUVOIR-A (15-m) and LUVOIR-B (8-m). In this presentation, we will review the Solar System observing capabilities of LUVOIR.

The High Definition Imager (HDI) instrument is the primary astronomical imaging instrument for observations in the near UV through the near IR. The HDI design provides a 2 x 3 arcminute field-of-view, taking full advantage of the angular resolution provided by the telescope, and consists of two channels – UVIS (200 nm - 950 nm) and NIR (800 nm - 2500 nm). HDI would enable orbiter- and flyby-quality observations of many solar system bodies, both large and small. For instance, Pluto, which has a spatially heterogeneous surface, can be spatially and spectrally characterized with LUVOIR. LUVOIR could also obtain images of Jupiter with resolution comparable to the JUNO orbiter, and it could perform long-term monitoring of many outer solar system bodies that have not been visited by spacecrafts in recent decades (e.g. Uranus, Neptune) at high spatial resolution.

This poster will incluude simulated observations of Solar System bodies with the LUVOIR-A and LUVOIR-B instruments. It will compare such observations with those from past, present and future space telescopes, using a conbination of real and simulated observations.

301.15 — Exoplanet Yield Estimates for the LUVOIR Mission Concept

Christopher C. Stark[1]

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The expected yield of potentially Earth-like planets is a critical metric for designing future exoplanet-imaging missions. The fidelity of yield estimates has recently advanced dramatically and now include detailed instrument performance simulations, improved stellar catalogs, and additional sources of background like solar glint and stray light from binaries. Importantly, we now include all major sources of astrophysical noise, allowing us to provide absolute yield numbers with astrophysical uncertainties. Using these high-fidelity simulations, we confirm previous results showing that exoEarth candidate yield is a weak function of all mission and instrument parameters except for one: telescope aperture. We show that obtaining a sample size for statistical studies of directly-imaged potentially Earth-like planets requires a mission of the scale of LUVOIR.

301.16 — The LUVOIR Mission Concept: Technologies to Enable the Next Great Observatory

Matthew Ryan Bolcar[1]

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The Large Ultraviolet/Optical/Infrared Surveyor (LUVOIR) is one of four mission concepts being studied by NASA for the 2020 Decadal Survey in Astronomy and Astrophysics. LUVOIR will be capable of a broad range of science, including: direct imaging and characterization of a wide range of exoplanets and the search for biosignatures on Earth-like planets around sun-like stars; studying galaxy formation and evolution; investigating star and planet formation; and remote sensing of bodies within the Solar System. Enabling a mission as ambitious as LUVOIR requires an array of technologies, such as ultra-stable structures and optics, precision metrology and wavefront sensing, high-contrast imaging techniques, large-format detectors with very low noise, and high-throughput ultraviolet instrumentation. Critically, a systems-level approach must be taken to developing these technologies, guided by architecture studies to place each technology in the appropriate system context. In this poster, we describe LUVOIR's technology needs, as well as current efforts that are actively developing these technologies. We will discuss recent advancements in: measuring picometer-level displacements of optical and structural elements; sub-millikelvin thermal sensing and control; non-contact vibration isolation for pointing and dynamic stability; coronagraph design for achieving 10^{-10} contrast on a segmented system; high-speed metrology for optical system alignment; low-order and out-of-band wavefront sensing for maintaining high-contrast images; low-noise detectors across the ultraviolet, optical, and near infrared bands; broadband coatings with high-reflectivity below Ly-α. We will also describe a systems approach to coordinating the development of these technologies to achieve the necessary maturity for a LUVOIR mission start in the next decade.

301.17 — The State of the Wide-Field Camera 3

Russell E. Ryan[1]; Sylvia M. Baggett[1]; Matthew Bourque[1]; Gabriel Brammer[1]; Annalisa Calamida[1]; Susana E. Deustua[1]; Harish G. Khandrika[1]; Jennifer Mack[1]; Myles McKay[1]; Norbert Pirzkal[1]; Elena Sabbi[1]; Ben Sunnquist[1]
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We will discuss the state of the Wide-Field Camera 3 instrument on the Hubble Space Telescope. In particular, we will describe our new implementation for anomalous pixels and their effects in a new bad-pixel tables. In conjunction with that, we have implemented new time-dependent dark reference images, which will be delievered to the archive. We will present analysis of the time-dependence of the photometric variability, photometric color terms, and grism trace and dispersion recalibrations for the UVIS detector. Finally, we provide suggestions, tips, and recommendations for Users preparing Phase 2 files.

301.18 — Transmission Spectroscopy of Exoplanets with LUVOIR

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Transmission Spectroscopy is one of our most powerful tools for characterizing exoplanet atmospheres, and thanks to the recent launch of NASA's TESS mission we will soon have a large sample of planets around bright stars, ideally suited to this technique. With it's unique combination of UV to NIR wavelength coverage and incredibly high S/N, LUVOIR would build upon the powerful legacy of Hubble and revolutionize our ability to characterize the atmospheres of a wide range of transiting exoplanets. At FUV wavelengths the LUVOIR Ultravoilet Multi Object Spectrograph (LUMOS) will obtain high S/N transmission spectra and high spectral resolution, allowing us to detect transiting planetary exospheres and constrain the physics of atmospheric escape. Meanwhile, using the UVIS channel on the High Definition Imager (HDI) instrument we can obtain high S/N R = 500 spectra in the optical and NUV, which allow us to constrain the properties of clouds and search for absorption from alkali metals. Finally, with the NIR channel in HDI we will be able to detect molecular absorption and measure abundances for a wide range of species including H2O, CO2, and O2.

302 — Solar Physics Division (SPD), Poster Session III

302.01 — Formation and Eruption of Magnetic Flux Ropes in the Solar Corona

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[3] *NASA Goddard (Greenbelt, Maryland, United States)*

Magnetic flux ropes in the solar corona are often thought to form the basis for both long-lived coronal prominences and for eruptive coronal mass ejections. In this presentation we discuss numerical simulations exploring how such flux rope structures can both be created and disrupted via the emergence of magnetic flux from the convection zone into the corona. The presentation will focus on the formation of these structures directly from flux emergence as well as the effects, both stabilizing and eruptive, that newly emerging flux can have on pre-existing coronal flux ropes.

This work is supported by the NASA Living with a Star program and the Chief of Naval Research.

302.02 — (withdrawn)

This abstract was withdrawn.

302.03 — NLTE inversions of Ca II 854.2 nm spectra from SOLIS/VSM: Temperature diagnostics

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We present non-local thermodynamic equilibrium (NLTE) inversions of Ca II 854.2 nm spectra from SOLIS/VSM observations. We show that precomputed spectra from a database of model atmospheres can be

applied for a reliable inference of temperature stratifications in the solar atmosphere. We show examples of such inferences in different solar structures such as the umbra, penumbra, circum-facular regions and the quiet Sun. We also fit full Stokes profiles assuming a simple magnetic model with an exponential dependence with optical depth to derive vector magnetic field information and compare with the values derived from the weak-field approximation.

302.04 — Preparing for DKIST: Connecting the High-Resolution Sun to the Turbulent Corona

Samuel Van Kooten[1]; Steven R. Cranmer[1]
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Magnetic bright points on the solar photosphere, visible in both continuum and G-band images, indicate footpoints of kilogauss magnetic flux tubes extending to the corona. The horizontal motions of these footpoints are believed to excite MHD waves which propagate to the corona, where they deposit heat through turbulent dissipation. Analyzing this motion can thus provide a power spectrum of MHD wave energy transport, which is a key lower boundary condition in coronal and heliospheric models. At $\sim$100 km in diameter, most bright points are seen as unresolved blobs. Tracking their centroids allows the excitation of kink-mode waves to be modeled in the overlying flux tubes. However, centroid tracking cannot easily handle the merging or splitting of bright points nor can it track extremely long bright points, and current observations cannot reveal more complicated motions, such as size or shape changes, which are expected to excite higher-order waves. DKIST promises to resolve the sizes and shapes of bright points. However, Agrawal et al. (2018) showed that centroid tracking is likely to experience a spurious "jitter" signal when applied to high-resolution data, and this limitation is in addition to the inability of centroid tracking to produce new insights from the new size and shape information. We present efforts to overcome these limitations by developing an algorithm to infer the horizontal plasma flow inside bright points at DKIST-like resolution (at which bright points are resolved but not large enough for traditional correlation-tracking techniques) and using these inferred flows to model the higher-order waves generated in the overlying flux tubes. By using output data from high-resolution MURaM simulations now, we expect to be prepared to analyze DKIST images soon after they become available next year. This work will estimate the significance of the contribution to the coronal heating budget of these more complex waves and so provide a more complete lower boundary condition for coronal and heliospheric models.

302.05 — Historical reconstruction of UV spectral indices

Serena Criscuoli[1]; Francesco Berrilli[2]; Mia Lovric[2]; Valentina Penza[2]
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Solar radiation is one of the major natural drivers of Earth climate changes observed from the Maunder minimum. UV radiation in particular plays a major role in the ozone production/destruction processes and is known to affect the circulation patterns. Here we present reconstructions of the FUV-MUV color index and CaII and MgII core-to-wing indeces from 1749-2015, performed with a semi-epirical approach. We also present a reconstruction of the TSI variability. Our results are compared with reconstructions obtained with models employed in climatological studies.

302.06 — What do we reliably know about how fast the Sun's core spins?

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Fossat et al. (2017) and Fossat & Schmider (2018) have attempted to use solar p-mode frequency perturbations to detect rotational splitting of g-modes. They claim that this approach detected the Sun's core to be rotating about 3.8 times faster than the surrounding radiative interior and the convection zone. We report an independent study of the technique, the inconsistencies with the well-established p-mode determinations of rotation, and with their assumption of which g-modes might be sensed. Additionally we used both the same calibrated 80s SOHO/GOLF data used in the 2017 study and the then only publically available GOLF 60s cadence data and verified the findings of Schunker et al. (2018) that the g-mode detection was fragile: It vanished when the GOLF data was sampled at the 60s vs 80s cadence and when the starting point was shifted by 2 hours of the 15 years studied. We also applied the same technique to all other available long duration low-degree data collections including SOHO/MDI, SOHO/LOI, SDO/HMI, GONG, and BiSON and found no evidence of the Fossat et al.

(2017) reported signals. We note that a second independent study by Appourchaux & Corbard (2019) came to the same conclusions. Thus we doubt the validity of the 2017 findings and conclude that there is no useful information about the rotation of the solar core yet determined using these techniques (Scherrer & Gough, 2019). References: Appourchaux, T., & Corbard, T. 2019, Submitted to A&A, Fossat, E., Boumier, P., Corbard, T., et al. 2017, A&A, 604, A40, Fossat, E., & Schmider, F. X. 2018, A&A, 612, L1, Scherrer, P. & Gough, D., Accepted by ApJ, 2019, Schunker, H., Schou, J., Gaulme, P., & Gizon, L. 2018, SoPh, 293, 95

302.07 — Temporal Evolution of the Sun's Interior Meridional Circulation during 2010 — 2018

Ruizhu Chen[1]; Junwei Zhao[1]

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The Sun's meridional circulation plays an important role in solar dynamo, which drives the Sun's magnetic-field variation cycles, and it is curious how the meridional circulation itself evolves with the solar cycle. In this study, we employ a newly-developed comprehensive time-distance helioseismic measurement scheme, make measurements using SDO/HMI Doppler-velocity observations from 2010 to 2018, and explore the temporal evolution of the meridional circulation over different phases of the current solar cycle. Our new measurement method measures acoustic travel-time shifts along all radial directions of the solar disk for all possible measurement distances, and removes the systematic center-to-limb effect through solving a set of linear equations. Measurements are made on every two-year data chunk to obtain the time-dependent meridional-flow-induced travel-time shifts, which show a significant change between the solar activity minimum and maximum. The travel-time shifts are then inverted for meridional flow in a least-square way. We show evidence of temporal variation of the meridional-circulation pattern over different phases of the cycle.

302.08 — Modeling of Subsurface Shear with EULAG-MHD

Andrey Maksimovich Stejko[1]; Gustavo Guerrero[2]; Alexander G. Kosovichev[1]

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The 3D Global solar convection algorithm EULAG-MHD has recently been used to recreate solar hydrodynamic profiles of differential rotation and meridional circulation along with simulation of long-term evolution of the global magnetic field. In previous studies we saw some of the large effects that are created by including strong shear layers in the tachocline and on the surface; changing the period of the solar cycle from an order of years to that of decades. We attempt to explore the global consequences of these regions by simulating various levels of sub/super-adiabaticity in the background potential temperature profiles – modeled by a polytropic ideal gas with manually controlled polytropic indeces, simulating the creation or suppression of a near-surface shear layer (NSSL). We also attempt to understand how the MPDATA algorithm that is implemented in the model will function under various resolutions (512 φ, 256 θ, 256 R; 256 φ, 128 θ, 128 R) where an implicit viscous dissipation is implemented using the implicit Large-Eddy simulation (ILES) approach for turbulent advective motions – a method that can be unpredictable as large changes in resolution begin to change scales of dissipation in low viscosity environments. The simulation of our NSSL is done at a lower resolution (128 φ, 64 θ, 64 R) that has repeatedly been shown to adequately simulate solar-like hydrodynamic effects such as differential rotation, as well as generate well defined cyclical magnetic dynamo patterns. These models show the NSSL as playing an important role in the proper distribution of angular momentum and resulting in more realistic solar-like magnetic and hydrodynamic patterns.

302.09 — Time-Dependent Hydrodynamic Modeling of Solar Acoustic Waves

John Stefan[1]; Alexander G. Kosovichev[1]

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We consider linear perturbations to appropriate hydrodynamic equations, such as mass continuity and the adiabatic condition. Using the Solar Model S (Christensen-Dalsgaard 1996- 2014) as mesh, we discretize the governing equations as well as decompose the various modes using spherical harmonics. We take advantage of parallel computing resources by running simulations up to very high modes of order l=3000. This allows us to model so-called "sunquakes" with fairly high precision; since the governing equations allow for different types of perturbations, we aim to determine the location and mechanism of these impulsive events.

302.10 — Active Region Flows and their Contribution to Varying Global Dynamics

Douglas Braun[1]
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We explore the general properties of the near-surface dynamics of solar active regions (ARs) and show how AR flows may contribute to longitudinally averaged measurements of global properties such as meridional circulation and torsional oscillations. Helioseismic holography is applied to HMI Dopplergrams yielding about 5000 flow measurements of 336 ARs observed by SDO between 2010 and 2014. Ensemble averages of the AR flows are presented, binned into subsets based on total magnetic flux. These averages show converging flows, with speeds about 10 m/s and spanning 10 degrees from the active region centers, which are apparent for most ARs above the flux limit of our survey at 10^{21} Mx. Retrograde flows are also detected, with amplitudes around 10 m/s, which predominantly, but not exclusively, flank the polar side of the ARs. The high signal-to-noise levels of these averages makes possible the assessment of individual AR contributions to time-varying global flows. We demonstrate this for several solar rotations, showing that individual active regions contribute substantially to these global flows.

This work is supported by the Solar Terrestrial program of the National Science Foundation (award AGS-1623844) and by the NASA Heliophysics Division (awards 80NSSC18K0066 and 80NSSC18K0068).

302.11 — (withdrawn)

This abstract was withdrawn.

302.12 — Spectropolarimetric diagnostics of coronal magnetic field from UV and visible/IR during solar minimum

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The invisible magnetic field in the corona plays an important role for solar activity, hence measuring the coronal magnetic field is highly desired. The linear polarization measurements in the saturated Hanle regime of visible/IR are already obtained by the CoMP telescope providing information about coronal magnetic direction and topology. Other observations such as linear polarization in UV unsaturated Hanle measurements provide important complementary information about the strength of 3D coronal field. Until such observations are available, we turn to the FORWARD model (Gibson et al. 2016) to explore how these polarization data might be used together to interpret the coronal magnetic field. As a physical state to input into FORWARD, the analytic magnetic model in this work is adopted from Gibson et al.(1996), which is an axisymmetric model and gives a potential field with an exception at the boundary of the helmet streamer where current sheets are added between the open and closed fields. The plasma model is adopted from Sittler&Guhathakurta (1999) and Vásquez et al. (2003), which is consistent with multi-observations. Given this model input of a 3D distribution of magnetic field and plasma for solar minimum, we obtain simulated polarization results in UV and visible/IR wavelengths. This allows us to consider how such observations might be used together in future to diagnose the coronal magnetic field.

302.13 — Retrieving 3D coronal magnetic field from ground and space based spectropolarimetric observations

Maxim Kramar[1]*; Haosheng Lin*[1]
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Solar coronal magnetic fields play a key role in the energetics and dynamics of coronal heating, solar wind, solar flares, coronal mass ejections (CME), filament eruptions, and determine space weather processes. Therefore, precise knowledge of the 3D magnetic field and thermodynamic structures of the corona is essential for the heliophysics community's effort to understand the physics of the solar wind and solar eruptive phenomena. With the recent advancement of scalar and vector tomographic inversion techniques (Kramar et al., 2016), it is now possible to directly derive the 3D coronal magnetic, temperature, and electron density structures using synoptic Fe XIII 1075 nm coronal emission line (CEL) linear polarization data of the Coronal Multichannel Polarimeter (CoMP, Tomczyk et al., 2008), and UV coronal images from STEREO mission. This is a major milestone in our effort to establish the capabilities to directly observe 3D magnetic and thermodynamic structures of the corona.

Although the vector tomography based on linear polarization (LP) data can be used to probe certain coronal field configuration (Kramar et al. 2013),

linear polarization data alone does not allow us to uniquely reconstruct all possible field configurations in general. In the near future, the arrival of DKIST will provide the multi-CEL full-Stokes data more accurate determination of the static corona using the rotation of the Sun to emulate tomographic observations.

On the longer term, observational determination of spatially and temporally resolved B(r; t), T(r; t), and n(r; t) will require the deployment of a *Space Coronal Magnetometry Mission* (SCMM) with a fleet of spacecraft observing the Sun from many non-redundant circumsolar orbits simultaneously.

We will discuss how the use of full Stokes polarization data and multiple observing geometry from and out of the ecliptic plane will improve the accuracy of coronal magnetic field reconstruction.

302.15 — Idealized MHD Simulations of Eruptions in the Solar Atmosphere

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We present a parameter study of numerical simulation designed to explain the onset of major solar eruptions from solar active regions. We investigate the likelihood of eruption based on the emerging magnetic flux and the pre-existing flux.

302.16 — Lyman-α imaging polarimetry with the CLASP2 sounding rocket mission

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Ultraviolet polarimetry offers a unique opportunity to explore the upper solar chromosphere and the transition region (TR) to the million-degree corona. These outer atmospheric regions play a key role in the transfer of mass and energy from the solar photosphere to the corona. With a sounding rocket experiment called the Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), in September 2015 we succeeded in obtaining the first measurement of the linear polarization produced by scattering processes in the hydrogen Lyman-α line of the solar disk radiation. The analysis and interpretation of such spectro-polarimetric observation allowed us to obtain information on the geometrical complexity of the corrugated surface that delineates the TR, as well as on the magnetic field strength via the Hanle effect. At the same time, the CLASP slit-jaw (SJ) optics system, which is a Lyman-α filter imager characterized by a FWHM= 7 nm, allowed us to obtain broad-band Stokes-I and Q/I images over a large field of view. The obtained broad-band Q/I images are dominated by the scattering polarization signals of the Lyman-α wings, and not by the much weaker line-center signals where the Hanle effect operates. Recently, Alsina Ballester et al. (2019, ApJ, in press) showed that the scattering polarization signals of the Lyman-α wings are sensitive to chromospheric magnetic fields via the magneto-optical effects. Therefore, Lyman-α imaging polarimetry is of scientific interest also for magnetic-field investigations. On April 11, 2019, we performed another sounding rocket experiment, called the Chromospheric LAyer Spectro-Polarimeter (CLASP2). We used the same instrument after significant modifications in order to obtain spectro-polarimetric observations of a plage and a quiet region in the ionized magnesium lines around 280 nm (i.e., the Mg II h & k lines). At the same time, the CLASP2 SJ optics system allowed us to obtain broad-band Q/I and U/I images at the Lyman-α wavelength, in addition to the well-known SJ intensity images. In this presentation, we provide a first overview of the CLASP2 SJ data.

303 — Stars & Stellar Evolution Poster Session

303.01 — Fundamental Stellar Parameters and Multiplicity Rates of M-Dwarfs through Optical Speckle and NIR AO Imaging

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We present preliminary fundamental stellar parameters and multiplicity rates of M dwarf stars using a combination of speckle imaging and adaptive optics. Our survey mainly uses the Differential Speckle Survey Instrument (DSSI) at Lowell Observatory's Discovery Channel Telescope (DCT). DSSI observes speckle patterns simultaneously at two separate wavelengths and the data for this project are composed of observations which span from 2016 to 2018. More recently, the speckle data for some of the target stars that have been found to be binary have been supplemented with observations using Adaptive Optics (AO) at Palomar Observatory. The combination of speckle data in the visible and AO data in the near-infrared allows us to make robust determinations of the luminosities and effective temperatures of the components in each case. Using the known Mass-Luminosity Relation, we also estimate the component masses. A discussion of interesting systems will be given.

303.02 — Update on a Survey of the Most Luminous Stars in M31 and M33

John C. Martin[1]
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Post-main sequence evolution of the most luminous stars significantly contributes to the chemical enrichment history of the universe. They also provide insight to extreme physics and unexplained eruptive behavior (i.e. supernova impostors and S Doradus eruptions) which are not normally predicted by stellar modeling. Unfortunately, because there are not as many to study, the later stages of massive star evolution are not as well observed and understood as the evolution of low mass stars. Heavy extinction in the plane our own galaxy makes the luminous/massive star populations in nearby galaxies easier observe at shorter wavelengths (where they emit most of their energy). Since 2012 we have monitored brightness changes of the most luminous stars in M31 and M33 with a targeted survey focused on luminous blue variables (LBV), candidate LBV, B[e] supergiants, and warm hypergiants. We report on the progress of this survey, focusing on trends emerging in the variability of the different classes of massive stars within the classifications studied.

303.03 — Using Gaia Parallaxes to Distinguish M31 Red Supergiants from Foreground Stars

Logan Michael Kimball[2]; *John C. Martin*[1]
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Galactic extinction complicates the study of many of the most massive stars in our own galaxy. Surveys of luminous stars in nearby galaxies contain many massive stars but those surveys must contend with the misidentification of dwarfs and AGB stars as supergiants (foreground contamination). Massey et al. (2009) built a list of several hundred M31 red supergiants (RSG) using color-color photometry and later Massey & Evans (2016) used radial velocities to further refine that list. We have cross-correlated those lists with high precision parallaxes from Gaia DR2 in order to determine the utility of Gaia parallaxes for distinguishing foreground sources and RSG and M31.

303.04 — The PolStar SMEX Mission — Science Drivers and Scope

Paul A. Scowen[1]
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PolStar is a FUV spectropolarimeter SMEX mission that is the first to combine the spectroscopic capabilities previously available in IUE and HST-COS with the polarimetric capabilities of a true successor to WUPPE. PolStar will provide access to the suite of resonance lines in the FUV to map the wind and magnetospheric structure of massive stars in 3D and gain insight into the effect these structures have on the mass loss and stellar evolution of the stars themselves. The mission will also address science related to how massive binary pairs interact with each other, and provide access to the interstellar reddening law at very short wavelengths for a variety of sight lines. The suite of science drivers is discussed in terms of requirements placed on the mission design and we outline the kinds of return we might expect from this mission, if selected.

303.05 — Simulating the Inner Asterospheric Magnetic Fields of Exoplanet Host Stars

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We study magnetic and energetic activity across a range of stellar behavior via the application of an observationally-based heliophysics modeling framework. We simulate the inner asterospheric magnetic fields of host stars with the aim of better understanding and constraining the space weather environments of exoplanets, and improving our knowledge of the solar-stellar connection. As astronomy instrumentation has improved, Earth-like exoplanets are increasingly being found orbiting in the habitable zones of a variety of stars, ranging from the smallest and coolest M dwarfs to larger and more solar-like stars. We are therefore interested in characterizing a broad range of stellar magnetic activity and the resulting impacts on asterospheric environments. We will present our work simulating stellar magnetic activity on cycle timescales via the integration of modeled magnetic flux emergence, coronal field structure and related plasma emission, and stellar winds. We use this self-consistent framework of heliophysics-based models to simulate stellar and asterospheric evolution, in order to better understand the dynamic connections between host stars and potential impacts on planetary space weather and habitability. We also remark on the comparative heliophysics approach which we plan to extend to star-planet interactions via coupling to models of magnetospheric activity and dynamo-driven stellar flux emergence.

303.06 — Automated Pipeline for the Continuous Monitoring of KIC 8462852 Using the Great Basin Observatory

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KIC 8462852 has puzzled astronomers since its aperiodic fluctuations in brightness and long- term secular dimming was discovered in 2016. Based on that initial data from the Kepler mission, an international collaboration has sought to better understand these two phenomena. Over the past three years, a network of observatories has been monitoring the star nightly in order to see these fluctuations in real time and send alerts to the community for further observation. The research presented here is in an effort to contribute to the continuous monitoring of KIC 8462852 using the Great Basin Observatory. Nightly observations are scheduled with ACP Observatory Control Software and an automated pipeline, using Python'sAstropy and IRAF has been set up to process the images and perform photometry in order to quickly recognize a dimming event. Since March of 2018, our data show the largest such event since the initial Kepler data and is consistent with other observations during that time. It also confirms the chromatic nature of these events, suggesting that the material obstructing the stars light is optically thin. Additionally, the secular dimming has not been witnessed and conversely, the star has portrayed a slight rising trend over this period.

303.07 — Developing a Python Package for Automated Mineralogical Compositional Analysis

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The circumstellar disk that surrounds a star is composed of the gas and dust particles that are in orbit around it. Around infant stars, this disk can act as a source of material that can be used to form planetesimals, which can then accrete more material and form into planets. The composition of these circumstellar disks is of importance because it can indicate either what future planetesimals are likely to be made of, or it can shed some light on the history of any planetesimals that have already formed. In this research project, we have created an automated computer program that will take in the spectra of a circumstellar disk as input and will output its most likely mineral composition and the relative abundances of each mineral. For the mineral spectra, we used the mid-infrared wavelength range because the inner section of the circumstellar disk, where planetesimals are thought to form, radiates strongest in mid-infrared light. The most likely mineral composition is found by using the linear least square minimization method on the observed circumstellar spectra data. The creation of this program will help to identify the possible mineral composition at a faster rate than could be done otherwise. The final mineral compositional analysis result can then be compared to various solar system objects such as comets and asteroids.

303.08 — BVR_cI_c Observations and Analysis of the Totally Eclipsing Very Short Period Algol Binary, V385 Camelopardalis

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V385 Cam is a F5V±2 type (T∼ 6500K) eclipsing binary. It was observed on December 15, 16, 17, and 18, 2017 at Dark Sky Observatory in North Carolina with the 0.81-m reflector of Appalachian State University. Three times of minimum light were determined from our present observations, which include two primary eclipses and one secondary eclipse: HJD Min I = 2457372.62072 ± 0.00034, 2457374.4578 ± 0.0042, HJD Min II = 2457372.9266 ± 0.0011. In addition, an ephemeris was given by Shaw, https://www.physast.uga.edu/~jss/ncb/. Other times of minima were given in BRNO and Diethelm 2013, An ephemeris was calculated by ASAS-SN, https://asas-sn.osu.edu/: JD Hel Min I 2457386.76033 + 0.6152709 × E. Eight times of low light were calculated using least squares fits to archived data from asas. The following quadratic ephemeris was determined from the available times of minimum light:

JD Hel Min I = (245157372.61838 ± 0.00063) d + (0.61527012 ± 0.00000077) × E - (0.00000000014 ± 0.00000000008) × E^2.

The weak period decrease may indicate that the mass is flowing from the secondary Lagrangian point to the primary component. BVR_cI_c simultaneous 2015 Wilson-Devinney Program (W-D) solutions gives a mode 5 classical Algol solution (secondary component filling its Roche Lobe, primary underfilling). The semidetached solution gives a primary component with a 93% fill-out. The solution gives a mass ratio of 0.2808 ± 0.0057, and a component temperature difference of ∼1500 K. The large ΔT in the components verify that the binary is not yet in contact. A Binary Maker fitted dark spot did not persist in the WD Synthetic Light Curve Computations even though there is a definite asymmetry at phase ∼0.75. The inclination is ∼83.1 ± 0.3 degrees, resulting in a total eclipse (secondary component) of 16.3 minutes in duration. The system's distance is 854 (±13) pc as determined from GAIA DR2. Additional and more detailed information is given in this report.

303.09 — Observations and Modern Light Curve Analysis of the Detached Solar Type Binary, AE Cas

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AE Cas was observed some 40 years ago by Srivastava and Kandpal (1984) and analyzed by a Fourier technique. This study represents the first modern synthetic analysis of light curves using the 2015 version of the Wilson-Devinney Program. V, R_c, I_c observations were taken October 3, 4 and 23, 2016 at Dark Sky Observatory in North Carolina with the 0.81-m reflector of Appalachian State University and remotely by the 0.9-m reflector at KPNO from the SARA consortia. Five times of minimum light were determined from our present observations, which include three primary eclipses and two secondary eclipses: HJD Min I = 2457663.5055 ± 0.0005, 2457684.76093 ± 0.00005, 2457684.7616 ± 0.0001; HJD Min II = 2457663.8843 ± 0.0006 and 2457664.652. In addition, eight observations at minima were introduced as low weighted times of minimum light taken from archived ASAS data and 74 times of minimum light from the literature, some being from visual observations. The following linear and quadratic ephemerides were determined from all available times of minimum light: JD Hel Min I = (2457684.7640 ± 0.0009) d + (0.75912076 ± 0.00000006) × E, JD Hel Min I = (2457684.75610 ± 0.00085) d + (0.75911881 ± 0.00000014) × E - (0.000000000047 ± 0.000000000003) × E^2. The period decrease may indicate the binary is undergoing magnetic braking and is approaching contact configuration. Otherwise, the near contact secondary component may be streaming matter onto the primary, more massive component. A BVR_cI_c simultaneous Wilson-Devinney Program (W-D) preliminary solution indicates the possibility that the system has a mass ratio somewhat less than unity (q = 0.856 ± 0.001), and a component temperature difference of ∼2060 K. The large ΔT in the components verifies that the binary is not yet in contact. No spots were needed for the solution, so if the stream exists it is week as verified by the small period decrease. Fill-out of our model is 83.2% for the primary component and 99.1% for the secondary component. The inclination is ∼76°, not enough for the system to undergo a total eclipse. The light curve in V is more than one magnitude in amplitude. Additional and more detailed information is given in this report.

303.10 — Constraining Tidal Dissipation in Low-mass Binary Systems

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Tidal interactions are known to drive the orbital evolutions in binary systems. As a result, the current rotation period of the primary star and the orbital eccentricity in the system depend upon the tidal dissipation efficiency in stars. The most widely accepted model is to assume a phase lag in the tidal bulge with respect to companion raising tides on the star. This phase lag is parameterized as Tidal Quality Factor (Q) which qualitatively determines the energy lost in a system due to tides. In this study, we use observed rotation periods of the stars and orbital eccentricities in several low mass Kepler binaries to constraint Q by running MCMC simulations. I present here the stellar and orbital evolution model used and the results and analysis of the simulations for a few of these systems. This study is aimed towards using a large number of binaries in order to explore the dependence of Q upon various observational parameters.

303.11 — A 25 Myr-old M+M eclipsing binary spanning the fully-convective boundary

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Although M dwarfs comprise the majority of stars in the Galaxy, a detailed understanding of these ubiquitous objects remains elusive. For example, current modelling struggles to accurately predict masses and radii in M dwarfs and this is especially true of pre-main sequence systems, where evolutionary models are poorly constrained observationally. Double-lined eclipsing binaries are key yardsticks for fundamental stellar parameters. However, due to the intrinsic faintness of such systems, there are currently only a few dozen M+M eclipsing binaries that can be used to robustly test models and only a handful of suitable pre-main sequence systems. We have recently identified and fully characterised a young (25 Myr), nearby (103 pc) eclipsing binary which is a member of the under-studied equatorial moving group 32 Orionis. We present the results of our joint light curve and radial velocity solution, including multi-year photometry from LCOGT, SkyMapper and TESS, combined with spectroscopy from Magelland/MIKE and the ANU 2.3-m/WiFeS spectrograph. The observations and modelling yield components of 0.5 and 0.2 solar masses, with radii in good agreement with 25 Myr isochrones and membership in 32 Orionis. Straddling the 0.35 solar mass fully-convective boundary for M dwarfs, the system is uniquely placed to test models of low-mass star formation, structure and evolution at intermediate epochs between the youngest star-forming regions and older open clusters like Praesepe and the Pleiades, where several new low-mass eclipsing systems have recently been found in K2 photometry.

303.12 — A Photometric Study of RR Lyrae Star TU UMa

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RR Lyrae stars are short-period, pulsating variable stars that are useful for determining cosmic distances. The goal of this investigation is to analyze photometric data of TU UMa, a variable star of RR Lyrae type, for distance determination. A comprehensive light curve was constructed from periodic optical observations using the Las Cumbres Observatory telescope network over the course of two weeks. The B, V, i, and Z filters were used and exposure times were adjusted for each filter. TU UMa has been studied extensively for about a century due to its status as the best candidate for an RR Lyrae star in a binary system. This project is part of a larger collaboration to study a set of RR Lyrae stars. Preliminary results will be discussed.

303.13 — Exploration of Compact Binary Systems Using Empirical Gaia Photometry

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We explore Gaia DR2 for new compact binary systems within 200 parsecs using a method based on reported mean G band flux uncertainties. More variable objects should have larger empirical photometric uncertainties. A preliminary list of candidate objects has been cross matched to known compact binaries. The next step in this work is to obtain follow-up high-speed photometry of the objects that were unknown before Gaia DR2. Follow-up observations will allow us to determine what kind of objects, if any, are preferentially selected by this method. Testing the reliability of this method for selecting candidate objects will be important for future Gaia data releases.

303.14 — Modeling the Evolution of Type IIb Supernovae in a Binary Circumstellar Medium

Christopher Kolb[1]; Stephen P. Reynolds[1]; Kazimierz J. Borkowski[1]; John M. Blondin[1]

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The presence of slow, dense stellar wind in binary systems can produce a highly asymmetric circumstellar medium (CSM), particularly for systems with a mass outflow velocity comparable to the binary's orbital velocity. Mass loss in such a system is significantly enhanced in the equatorial plane, with a resulting polar-to-equatorial density contrast of 10 to ~300. We aim to better understand this asymmetric CSM in the context of supernovae IIb progenitors and to study the impact on supernova morphology and resulting observational signatures.

We model the asymmetric wind and subsequent supernova explosion with full 3D hydrodynamics using the shock-capturing hydro code VH-1 on a spherical yin-yang grid. We investigate a range of CSM parameters including companion-to-primary mass ratios spanning 0.7-2.5, asymptotic wind speeds between 15-25 km/s, and orbital-to-wind velocity ratios ranging 1.0-2.0. For each, the resulting CSM is used to evolve a blastwave out to a few tens of years. In some cases, the blastwave remains quite asymmetric for years, maintaining a polar-to-equatorial radius ratio >2.5. We discuss this morphology and the observational implications of the resulting data, with a focus on radio brightness from a few weeks to months.

303.15 — Age of the Open Cluster NGC 752 from the Eclipcing Binary DS And.

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We present a new analysis of the 1.01-day period eclipsing binary star DS And in the nearby open star cluster NGC 752. We have measured high-precision light curves in *B*, *V*, *R* and *I* filter bands, clearly showing a total secondary eclipse. From a spectral disentangling analysis we also precisely measured the radial velocity variations of both stars using HET HRS spectra. Together these measurements allow us to determine the mass and radius of each star. We find that the primary star has M_1=1.76 $M_\odot$ and R_1=2.20 $R_\odot$, while the secondary star has M_2=1.22 $M_\odot$ and R_2=1.20 $R_\odot$. In the color-magnitude diagram of the cluster, the primary star is located at the main sequence turnoff where it is beginning rapid changes after its core hydrogen burning phase. By using the rapid radius change of the more massive star, we will determine an accurate age for the cluster using theoretical stellar models. We gratefully acknowledge support from the NSF under grant AST-1817217.

303.16 — The K2 M67 Study: Star Masses in an Old Open Cluster from a New Eclipsing Binary

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We analyze *Kepler* K2 photometry and ground-based radial velocities for the binary Sanders 617. This eccentric binary was discovered to have only one eclipse per 62.595 d orbital cycle, but because of the long period, the inclination of the binary and the stellar masses are tightly constrained. Because there is an extensive literature of M67 photometry from the ultraviolet to the infrared, we have developed a method to use the spectral energy distributions of cluster members to decompose the light of the binary into single cluster stars. The primary star has a mass of 1.22 $M_\odot$ and resides at the lower turnoff (the fainter of two maximums in $T_{\rm eff}$) for the cluster. While models are able to match the masses and photometry of the fainter star in the binary and solar analogs in the cluster, the brighter star in the binary is significantly fainter than model predictions using the *Gaia* cluster distance. This points to issues with conventional stellar models having masses slightly above solar. We are grateful for funding from the

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303.17 — High Precision Measurement of the Atlas Binary System Masses

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The Pleiades is a well-studied cluster with both white dwarfs and massive, young stars. We present new measurements of the radial velocities for both stars in the interferometric binary Atlas in the Pleiades star cluster using the spectral disentangling method. Our large collection of archival spectral data allows for more complete coverage of the radial velocity curve. In particular, the extremes of the curve are much better sampled. We use these measurements along with interferometric and lunar occultation measurements of positions on the sky orbit to more precisely measure the orbital parameters. This in turn gives a more precise measurement of the stellar masses. Along with the evolutionary state of the Atlas stars from photometry and the cooling time of the white dwarfs, this greatly improves the initial mass determination of the Pleiades white dwarfs for the initial-final mass relation. This will provide an independent determination of the age of the Pleiades that can be used to test other measures of the age, such as the lithium depletion boundary.

304 — iPoster Session: The Sun, Solar System & Public Policy

304.01 — The Comet Iwamoto (C/2018 Y1)

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Comet Iwamoto was discovered by Masayuki Iwamoto on december 20, 2018. This comet has an orbital period of 1,371.3 years [1], and its next passage around the sun will occur in the year 3390. The comet was closer to the earth on February 12 and its distance to our planet was 45 million kilometers. The perihelion occurred on February 7 [2]. The comet reaches aphelion far beyond the Kuiper Belt in the world of Severe Trans-Neptunian Things [3]. This comet is traveling at a speed of 238,099 km/h, relative to Earth [4]. From our Observatory, located in Pasto-Colombia, I captured several pictures, videos and astrometry data during several days. The animations were published by SPACEWEATHER on the following dates: February 14 [5] and February 23 [6]. The pictures 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. We obtained the following orbital parameters: eccentricity = 0.9920 ± 0.0148, orbital inclination = 160.405 ± 0.031 deg, longitude of the ascending node = 147.484 ± 0.011 deg, argument of perihelion = 358.06 ± 0.06 deg, perihelion distance = 1.287039 ± 0.000636 A.U, mean motion = 0.00048 ± 0.00134 deg/d, absolute magnitude = 12.2. The parameters were calculated based on 77 observations (Feb. 14-23) with mean residual = 0.19 arcseconds. I also obtained the light curve of the body with our data.

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[5]http://spaceweathergallery.com/indiv_upload.php?upload_id=151903
[6] http://spaceweathergallery.com/indiv_upload.php?upload_id=152114

304.02 — Using Numerical Simulation to Consider the Observed Variations in the Behavior and Appearance of Dark Spots on the Ice Giants

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The most recent observation of a dark spot on Neptune (Simon et al., 2019) is the latest confirmation that these vortices are a not uncommon feature in the atmospheres of the Ice Giants. With observations of more than a half-dozen of these vortices since the Voyager II encounters, we are now in a position to start categorizing the nature of these features and try to determine what drives their different properties and behaviors. These behaviors can include

latitudinal and longitudinal drift, shape oscillations, and the formation of companion clouds. Simulations of these dark spots with EPIC GCM (Dowling et al., 2006) can capture all of these behaviors, providing a diagnostic tool that can investigate the underlying physics of the observed phenomena. However, these simulations have generally targeted a specific feature such as the 1989 Great Dark Spot (GDS-89) or the Uranian Dark Spot (UDS), as opposed to developing a consistent understanding that captures the observed characteristics of all known dark spots. This more generalized work targets the effect of spot size, shape, and strength on its subsequent evolution, examining for example its interaction with the zonal wind shears to generate drift or a lack of drift or the existence of orographic uplift-driven condensation that may or may not generate companion clouds. This systematic simulation of multiple vortices and comparison of the results aims to reveal the key physics that govern the observed differences between the increasing number of recorded dark spots, creating stronger links between the simulations and future observations.

304.03 — Numerical Simulations of Uranus' Berg Feature as a Vortex-Driven Cloud under Varying Background Vorticity Gradients

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The Uranian Berg feature, first identified in the early 2000's, was a notable cloud feature in the southern hemisphere known for its visible similarity to an iceberg drifting off the Southern Polar Collar. This methane ice cloud remained in the region of 34° South until 2005 when it began a four-year equatorward drift spanning roughly 20° (de Pater et al., 2011). Similar behavior has been observed for some large-scale geophysical vortices (dark spots) on the Ice Giants (Uranus and Neptune). Most notably, the original Great Dark Spot (GDS-89), observed by Voyager II at Neptune, featured an equatorward drift of its own over at least 10 degrees (Sromovsky et al., 1993). The dark spots are so named for their darker contrast to the surrounding atmosphere and for several spots this contrast is further offset by bright orographic companion clouds that form above the vortex. While the Berg did not feature any such dark contrast, the persistent bright clouds and drifting behavior suggests that the Berg may have had an underlying vortex beneath the observed cloud that was too deep or insufficiently strong to develop visibly. This could account for the cloud's longevity as well as the drift in latitude. Smith and Ulrich (1993) postulated that the gradient of the background absolute vorticity played a key role in vortex dynamics. To better understand this phenomenon, the EPIC GCM (Dowling et al., 2006) was used to simulate the existence of a dark spot in the observed region for the Berg. Multiple simulations featuring various background vorticity gradients have been applied to investigate the relationship between vorticity gradient and spot drift rate. This relationship will then be utilized to determine an acceptable background vorticity gradient field to simulate drift features comparable to the Berg's observed drift rates.

304.04 — Simulating Saturn's A ring edge with a single chain of gravitationally-interacting particles

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The edge of the A ring, located 136,769 km from Saturn, has a 7-lobed pattern that appears and disappears every 4 years as the nearby satellites Janus and Epimetheus swap their orbital positions. While Janus is in the inner position, its 7:6 resonance from Janus is located only ~ 4 km inside the ring. This excites the 7-lobed normal mode on the ring edge, and the feature disappears as Janus moves from the inner position to the outer. We wish to model this satellite-ring system and have, accordingly, developed a new code to do so. We modified the N-body code, *hnbody*, to simulate narrow rings and ring edges using a single chain of gravitationally-interacting particles. We have tested our code on isolated resonances and can reproduce normal mode patterns including the 7-lobed feature in the A ring. However, the outer portion of the real A ring is perturbed by several resonances. The four most important resonances are The Lindblad Eccentric Resonances from Janus and Epimetheus that affect the eccentricities and the Corotation Eccentric resonances from each satellite that primarily affect the semi-major axes. Moreover, these four resonances move rapidly as the satellites swap orbital positions. We apply our new code to simulate the A ring edge with both satellites present and we are able to study the global patterns on the ring due to the action of multiple resonances. In this talk, we will describe how the outer parts of A ring change over a Janus-Epimetheus orbital period in our simulations and we will compare our results to observations.

305 — iPoster Session: Solar Physics Division (SPD), Session III

305.01 — A CME-Producing Solar Eruption from the Interior of an Emerging Bipolar Active Region

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In a negative-polarity coronal hole, magnetic flux emergence, seen by the Solar Dynamics Observatory's (SDO) Helioseismic Magnetic Imager (HMI), begins at approximately 19:00 UT on March 3, 2016. The emerged magnetic field produced sunspots, which NOAA numbered 12514 two days later. The emerging magnetic field is largely bipolar with the opposite-polarity fluxes spreading apart overall, but there is simultaneously some convergence and cancellation of opposite-polarity flux at the polarity inversion line (PIL) inside the emerging bipole. In the first fifteen hours after emergence onset, three obvious eruptions occur, observed in the coronal EUV images from SDO's Atmospheric Imaging Assembly (AIA). The first two erupt from separate segments of the external PIL between the emerging positve-polarity flux and the extant surrounding negative-polarity flux, with the exploding magnetic field being prepared and triggered by flux cancellation at the external PIL. The emerging bipole shows obvious overall left-handed shear and/or twist in its magnetic field. The third and largest eruption comes from inside the emerging bipole and blows it open to produce a CME observed by SOHO/LASCO. That eruption is preceded by flux cancellation at the emerging bipole's interior PIL, cancellation that plausibly builds a sheared and twisted flux rope above the interior PIL and finally triggers the blowout eruption of the flux rope via photospheric-convection-driven slow tether-cutting reconnection of the legs of the sheared core field, low above the interior PIL, as proposed by van Ballegooijen and Martens (1989, ApJ, 343, 971) and Moore and Roumeliotis (1992, in Eruptive Solar Flares, ed. Z. Svestka, B.V. Jackson, and M.E. Machado [Berlin:Springer], 69). The production of this eruption is a (perhaps rare) counterexample to solar eruptions that result from external collisional shearing between opposite polarities from two distinct emerging and/or emerged bipoles (Chintzoglou et al., 2019, ApJ, 871:67).

This work was supported by NASA, the NASA Postdoctoral Program (NPP), and NSF.

305.02 — High-resolution Observations of Dynamics of Superpenumbral Hα Fibrils

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We present unprecedented high-resolution Hα observations of a small solar pore in NOAA Active Region 12661, using the 1.6 m Goode Solar Telescope (GST) equipped with high-order adaptive optics at Big Bear Solar Observatory (BBSO). The observations reveal copious fine-scale chromospheric superpenumbral fibrils (with a cross-sectional width of $\sim$0.15″) around the pore, along with associated transit and intermittent flows with apparent speeds of 5-20 km s^{-1}. The wavelet analysis suggests that the observed flows along fibrils are not likely a manifestation of oscillations, but rather collections of actual counterstreaming mass motions. The observed flow is interpreted as siphon flow. In addition, the three-dimensional potential field model indicates that the pore and the surrounding fibrils are enclosed by fan field lines forming a separatrix dome configuration. We suggest that such a magnetically confined configuration may help to maintain the steadfastness of the superpenumbral fibril dynamics.

305.03 — Terminators: Predicting the end of sunspot cycle 24 and its impacts on space weather, weather and climate.

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Recent research has demonstrated the existence of a new type of solar "event." Unlike the signature events in the corona, flares and Coronal Mass Ejections, this event, the Terminator, takes place in the solar interior (at the Sun's equator), signalling the end of a magnetic activity cycle and the start of a sunspot cycle at mid latitudes – all at the same time. Observations indicate that the hand-over between the termination of the magnetic activity cycle and the blooming of the next sunspot cycle could be very short, possibly much less than a solar rotation.

Here we demonstrate the impact of these terminators on the Sun's radiative output and particulate shielding of our atmosphere through the dramatically rapid reconfiguration of solar magnetism. Using direct observation and proxies of solar activity going back six decades we can, with high statistical significance, demonstrate an apparent correlation between the solar cycle terminations and the largest swings of Earth's oceanic indices – a previously overlooked correspondence.

We then use a standard method in signal processing, the Hilbert transform, to investigate the presence, and identify the signature, of terminators in solar magnetic and radiative proxies. Using many decades of such data we can achieve higher fidelity on terminator timing than previous estimates have allowed.

The distinct signature presents a unique opportunity to project when the next terminator will occur, April 2020 (± two months) and sunspot cycle 25 will commence its growth phase. Further, April 2020 implies cycle 24 will only be 9.25 years long; we offer an explanation as to why cycle 24 is short (or rather, why cycle 23 and its "unusual solar minimum" was so long).

Finally, should a major ENSO swing follow next year, our challenge becomes: when does correlation become causation and how does the process work?

305.04 — Coronal Magnetic Field Topologies of Solar Active Regions

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The magnetic field overlying the coronae of solar active regions displays many complex configurations. In this work, we show renderings of the important topological surfaces corresponding to potential fields above solar active regions. Common geometries are identified, such as nested domains of connectivity, and the presence of narrow channels of open flux having high expansion factors. Additionally, a sequence of magnetic field topologies is used to demonstrate null-point creation and annihilation. Due to the presence of electric currents, the real coronal magnetic field topology is expected to be even more complex than that found in these potential fields.

305.05 — On the search of active region emergence precursors using acoustic power maps and travel time anomalies derived from time-distance analysis of HMI observations

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I present initial results from a systematic look at possible indicators of active region emergence precursors using acoustic power mapping and time distance travel time anomalies. Using HMI observations I have analyzed a set of active regions that have emerged at low latitudes and close to the central meridian. Since these regions emerged close to disk center, they could be tracked for days before and after their emergence. Data cubes of tracked surface images of various lengths were analyzed using both intensity and velocity observations. While each active region exhibits particular properties, this systematic approach allowed me to look at a few statistical properties that will be summarized. Namely the trade-off between precision and resolution, both temporal and spatial resolution, and the correlation between various metric of surface activity and its impact of the measured acoustic signal, whether seen in power map (filtered or not) or travel time anomalies derived from a time-distance analysis (also using a few different filtering).

306 — iPoster Session: Supernovae, AGN & Galaxies

306.01 — Core-Collapse Supernova Light Curves

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Core-collapse supernovae are challenging phenomena to simulate realistically from first principles. Light curves from such events provide an abundant source of data, helping to constrain theoretical models. They can be used indirectly to determine the possible kinetic energies, masses, and compositions of the explosion outflows. In this project, we take a suite of core-collapse supernovae models with various explosion energies, and post process to generate light curves. The progenitor masses used are 15, 20, and 25 $M_\odot$. We use the radiative transfer code SuperNu to construct the light curve data. We then compare our results to observed core-collapse light curves to identify realistic explosion models from the suite.

306.02 — Magnetohydrodynamic Jet Simulations for Radio-loud AGN

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We present three-dimensional magnetohydrodynamic jet simulations relevant to extragalactic radio galaxies and quasars. We utilized an updated Athena++ code to incorporate magnetic fields into previously computed high-resolution hydrodynamics simulations. In addition to identifying the turbulence and shock structures within the jet and cocoon, we explored the change of jet behavior resulting from by the effects of dynamically important magnetic fields. We examined the different jet propagations for a variety of jet velocities, jet-to-ambient gas density ratios and different magnetic field strengths and morphologies within the jet stream and in the surrounding medium. These comparisons of the behaviors of the MHD jets allows us to better categorize each jet's outcome as either a Fanaroff-Riley I (jet-dominated) or FR II (radio lobe-dominated) radio-loud active galactic nucleus. We also compared the results produced from simulations with different resolutions and noted increases in turbulence and jet asymmetry at higher resolution.

306.03 — Where do Obscured AGN fit in the Galactic Timeline?

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X-ray bright active galactic nuclei (AGN) are predicted to follow an extended stage of obscured black hole growth, after which they produce most of their feedback. In support of this picture we examine the most heavily obscured AGN in three different fields and compare their host galaxies with X-ray bright AGN. We examine galaxies (M > $10^{9.5}M_\odot$ for the presence of AGN at redshifts z = 0.5 - 3 in the COSMOS, EGS, and GOODS-S fields. We select AGN in the infrared and correlate different infrared selection techniques to assess their reliability. This includes probing the full shape of the IR spectral energy distribution by combining *Herschel* and *Spitzer* colors, 250/24 μm and 8/3.6 μm. 250/24 traces the ratio of the far-IR to mid-IR emission; lower ratios correlate with AGN heating. 8/3.6 traces the stellar bump; in this regime AGN radiation will outshine the stellar bump. These colors were correlated with full SED fitting for a few sources to verify the accuracy of this method. These IR colors allow us to select AGN within strongly star forming host galaxies. Of galaxies investigated, 50% reveal evidence of dust heating surrounding super-massive black holes, but lack an X-ray detection. We X-ray stack these galaxies to obtain hard and soft fluxes, allowing us to measure the energetics of these AGN. Stacking allows us to determine obscuration and X-ray luminosities to calculate accretion rates. Results show that these galaxies are more extended and have higher SFRs than their unobscured counterparts. This work demonstrates that there is a higher population of obscured AGN than previously thought. Our results fit in with the paradigm where obscured AGN directly proceed an unobscured phase, this unobscured phase is followed by quenching of star formation.

306.04 — A New Population of Cold Quasars

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AGNs are the most luminous objects in the universe, and the most massive ones are usually created by the merger of two gas-rich disk galaxies. This gas fuels an AGN through an accretion disk that emits at optical/ultraviolet wavelengths. This accretion disk can be obscured by a dusty torus that emits mostly in the IR waveband. Towards the center of the AGN, an energetic corona emits in the X-Ray waveband. We have identified >1800 X-ray luminous AGN in a 16 deg^2 region of the Stripe82 field surveyed by XMM-Newton and Herschel. Given the detection limits of Herschel, only 10% of our AGN have both an X-ray detection and an IR detection, providing unique insight into the fraction of luminous AGN surrounded by an abundance of cold dust. We coin these IR bright, type-1 AGN "cold quasars". We demonstrate that many of these cold quasars are in the canonical coalescence phase by examining SDSS imaging. However, just as many appear to be isolated point sources, challenging the merger scenario. We compare the IR luminosity and X-ray luminosity with less X-ray luminous AGN from z=1-2 (from COSMOS and GOODS-S) and find cold quasars to have proportionally more X-ray emission at a given infrared luminosity. This is likely due to the IR emission arising from the host galaxy, while the X-ray emission comes from the AGN component. We also compare the amount of dust mass in these cold quasars with the dust mass of star formation galaxies at the same redshifts and find it to be comparable. This then supports the picture where the quasar component is just beginning to become luminous, but has not blown out any of the host galaxy gas and dust.

306.05 — Accretion History of AGN: Measuring Black Hole Masses in Cold Quasars

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In the SDSS Stripe 82X field, the Accretion History of AGN (AHA) collaboration has assembled a multiwavelength dataset of thousands of X-ray luminous AGN. From this parent population, we select quasars in host galaxies at z<1 which are also strongly star forming, as measured in the far-IR. This yields 59 quasars which have far-IR star formation rates, X-ray luminosities, spectroscopic redshifts, and SDSS optical spectra covering the broad emission line region. Eight of the 59 galaxies exhibit broadening of the H-α emission, which we use to measure black hole mass. The broadening behavior of the line is caused by the motion of the gas under the gravitational influence of the black hole. We fit Gaussian models to the broad emission line and to the narrow H-α peak in order to separate these two physically distinct components. We use the flux and FWHM of the H-α line to estimate the black hole mass. We combine these masses with the bolometric luminosities (calculated from the X-ray luminosities) to determine each quasar's Eddington ratio, a measure of how efficient the black hole is at accreting mass. We compare the Eddington ratios for our quasars with published literature values to determine if quasars that are still forming stars (at rates >50 Msun/yr) show enhanced or decreased activity with respect to other samples.

306.06 — The offset of Brightest Cluster Galaxies from their parent cluster core

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A Brightest Cluster Galaxies (BCG) is the brightest galaxy in a cluster of hundreds to thousands of galaxies. These monsters are some of the biggest, brightest, and most massive galaxies in the universe. Characterizing a BCG can help discover more about galaxy evolution - the aging, evolution, merging history of galaxies. This project involves determining the separation of the peak of X-ray emission of the galaxy cluster, and the location of the BCG. We do this to characterize the system as being disturbed or undisturbed. We have found that ~17% of the 23 systems we observed have large separations, and thus may have undergone a recent merging event. Preliminary results on the age, metallicity and kinematics of the BCGs with large and small systems will be compared and presented.

306.07 — The distribution of ages, metallicities and dynamics of stellar populations in 23 BCGs using the SparsePak IFU

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Local Brightest Cluster Galaxies (BCGs) are the most massive galaxies in the local universe and have had the full age of the universe to build. We present the radial profile of ages, metallicities, and dynamics of 23 BCGs observed using the SparsePak instrument on WIYN by running the STARLIGHT stellar population synthesis models. Preliminary results of the stellar populations for different regions of the BCG, such as its core and outskirts, the intracluster light (ICL), and close companions of the BCG, are presented. The BCG core is found to host an older, more metal-rich population of stars than those found within the ICL. Analysis of the velocity dispersion as a function of the distance from the galactic center yields a rising or flat profile for ~70 percent of our X-ray selected sample.

306.08 — Antila2: the dark dwarf galaxy that crashed into the Milky Way

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Some time ago, we analyzed perturbations in the outer gas disk of the Milky Way (Chakrabarti & Blitz 2009) and predicted how massive and how close a dark-matter dominated dwarf galaxy would have to get to produce the disturbances in the outer HI disk of our Galaxy. The prediction was that a massive dwarf galaxy (about one-hundredth the mass of our Galaxy) with a close pericenter approach (about 7 - 10 kpc) was needed to explain the large perturbations at the edge of our Galaxy. We also predicted that it would currently be at a distance of ~100 kpc from the Galactic center. Many of the observed parameters of the Antlia2 dwarf galaxy are similar to our prediction from ten years ago. Using the observed Gaia proper motions of the Antlia2 dwarf galaxy, we have determined its orbital distributions, and its effect on the Galactic disk. The low pericenters of the orbital distribution are sufficent to explain the observed disturbances in the outer HI disk of the Milky Way. Such an interaction, i.e., very similar to our prediction in Chakrabarti & Blitz (2009), also reproduces the velocity sub-structures seen in the Gaia DR-2 data. We argue therefore that the giant, yet faint, dwarf galaxy Antlia2 is the very likely the culprit that produced the ripples in the outskits of the Milky Way.

307 — iPoster Plus IX: (SPD) Eruptions, Photosphere/Chromosphere, Helioseismology and Solar Interior

307.01 — The Global EUV Wave Associated with the SOL2017-09-10 X8.2 Flare: SDO/AIA Observations and Data-constrained MHD Simulations

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While large-scale extreme ultraviolet (EUV) waves associated with coronal mass ejections (CMEs) and solar flares are common, the EUV wave triggered by the X8 flare-CME eruption on 2017 September 10 was an extreme. This was, to the best of our knowledge, the first detection of an EUV wave traversing the full-Sun corona over the entire visible disk and off-limb circumference, manifesting a truly global nature. In addition to commonly observed reflections, it had strong transmissions in and out of both polar coronal holes, at elevated wave speeds of >2000 km/s within them. With an exceptionally large wave amplitude, it produced significant compressional heating to local coronal plasma. We present detailed analysis of SDO/AIA observations, global magnetic field extrapolations with the potential-field source surface (PFSS) model, and data-constrained MHD simulations of this event using the University of Michigan Alfven Wave Solar Model (AWSoM). By comparing the observations and simulations, we benchmark diagnostics of the magnetic field strengths and thermal properties of the solar corona on global scales. We discuss the future prospects of using such extreme EUV waves as probes for global coronal seismology, an area yet to be fully exploited.

307.02 — Transient dynamics and energy transfer from the photosphere to the low corona: initial results from a coordinated ALMA, DST, *Hinode*, IRIS, and SDO observation campaign

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We present initial results from a coordinated observation campaign to study transient dynamics and energy transfer in the low solar atmosphere. The observations ran from approximately 2017-03-21 from 13UT to 19UT, and include data from *Hinode*, IRIS, DST, and ALMA. The target, a small, magnetically bipolar active area associated with a coronal bright point, was chosen for showing reasonable dynamics in the chromosphere (as dictated by AIA 304 data from the day prior), and being near disk center to better facilitate magnetic field measurement. The campaign was designed to capture the dynamics of the target with as rapid a timescale as possible for each instrument. Photospheric dynamics are available from broadband IBIS data and the HMI. New to this dataset, the chromospheric dynamics were observed in radio frequencies using ALMA (Band 3: 92-108GHz) at a 2s cadence. Additional chromospheric data are spectral H-α from the IBIS instrument at the DST, spectropolarimetic HeI 10830 from the FIRS instrument at the DST, and the medium linelist from IRIS; coronal data includes imaging from XRT and spectral data from EIS. In this first set of results, we discuss the frequency of transient brightenings observed in each set of imaging data and how the spatial distribution relates across each data channel and to the regions magnetic topology.

307.03 — Detection of Dynamo Waves in the Solar Convection Zone by Helioseismology

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Analysis of helioseismology data obtained in 1996-2019 for two solar cycles from two space missions, Solar and Heliospheric Observatory (SoHo) and Solar Dynamics Observatory (SDO), reveals that latitudinal variations of solar rotation ('torsional oscillations') are associated with hydromagnetic dynamo waves initiated in the solar tachocline and travelling in radius and latitude towards the surface during the solar cycles. On the surface, the waves form two branches of zonal deceleration migrating towards the poles and equator, and coinciding with the large-scale magnetic field patterns observed in synoptic magnetograms. The results explain the phenomenon of 'extended solar cycle', and provide first observational evidence for magnetic dynamo waves predicted by the Parker's theory of solar activity cycles. We compare the observational results with dynamic models of the solar dynamo, and discuss driving mechanisms of the torsional oscillations.

307.04 — (withdrawn)

This abstract was withdrawn.

307.05 — Modeling observables for local helioseismology.

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Local helioseismology provides different techniques to study flows in the solar interior. However, all of them suffer from systematic errors, which occur because of the nontrivial relationship between wave displacement and helioseismic observables, such as intensity and Doppler velocity. In this study, we solve the radiative transfer equation in a perturbed solar atmosphere including flows caused by acoustic oscillations. The adiabatic oscillations for normal modes of low and high degree are computed using the ADIPLS code that solves an eigenvalue problem in a standard solar model assuming spherically symmetric background quantities. The wave displacement causes perturbations in atmospheric thermodynamical quantities that, in turn, perturb opacity and emergent intensity. These perturbations depend on the center to the limb distance. In addition, the oscillations modify the shape of the solar surface and thus the direction of the normal to the surface. For low-degree modes this geometrical effect is negligible, however, this effect matters for high-degree modes with a large horizontal component of wave displacement. We investigate the contribution of such perturbations on emergent intensity and velocity and estimate their impact on helioseismic observables.

307.06 — Listening to the Sun: the Sonification of Solar Harmonics Project

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Helioseismology has enjoyed far-reaching success over the last few decades. Not only has it enabled physical inferences of unprecedented precision, but when one learns for the first time that the Sun is a resonant cavity for low frequency sound waves, the reaction is almost always one of wonder and awe. The question naturally arises: "What does it sound like?". Unfortunately, until now, helioseismologists have rarely been able to give a satisfying response. Although we spend our days studying sound waves, we never listen to our data. The purpose of the Sonification of Solar Harmonics (SoSH) Project is to make such listening accessible to scientists and nonscientists alike.

We have developed software that closely mimics global-mode helioseismic data processing and also uses the results thereof. The SoSH Tool, as we have called it, filters real solar data and transposes it up to the range of human hearing, all the while preserving the frequency relationships between the modes. In other words we retain the musical intervals between solar harmonics, thus enabling one to use the Sun like a musical instrument.

Creative applications are not the only use of the SoSH Tool. Sonification has been used extensively in the study of geoseismology as well as other types of solar data. Thus, we have reason to suspect that the auditory modality may also have advantages over purely visual display when it comes to helioseismology. Further, we already know that solar rotation is easily heard in the sonified data, as well as the so-called small frequency separation, which is sensitive to conditions in the solar core. If we sacrifice the musical intervals between tones, we can also hear the solar cycle.

Several extensions and new applications of the SoSH Tool are underway. We have written a python module to create graphical representations of the modes we sonify. This will eventually lead to full-dome planetarium presentations of the interior of the

Sun. The SoSH Tool is able to combine solar harmonics in a variety of ways, and this will enable the composition of a solar concerto. As we sonify and make public larger volumes of sonified data, we hope to not only spread knowledge of helioseismology, but perhaps to also reap new scientific insights.

308 — Cosmology & Related Topics

308.01 — The Limitations of Redundant Calibration for Radio Interferometry and 21 cm Cosmology

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The idea of redundant calibration has a long history in radio interferometry, but has drawn renewed attention over the last several years for its potential to mitigate systematics in 21 cm cosmology experiments. In this talk, I will show results from both simulations and the analysis of real data that demonstrate the limitations inherent to redundant calibration. In particular, many of the frequency-dependent calibration errors that plague 21 cm cosmology cannot be mitigated by redundant calibration. Without alternative methods, "traditional" sky-based calibration schemes remain an essential part of a 21 cm cosmology analysis pipeline – and the challenges associated with sky-based calibration must continue to be addressed.

308.02 — Stability analysis using dynamical systems in modified gravity

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Modified gravity theories have received increased attention lately to understand the late time acceleration of the universe. This viewpoint does not need undetected candidates like dark energy and dark matter at fundamental level and it takes into account only the "observed" quantities. Among numerous extension to Einstein's theory of gravity, theories which include higher order curvature invariant, and specifically the class of f(R) theories, have received several acknowledgments. In our current work we try to understand the late time acceleration of the universe by modifying the geometry of the space and using dynamical system analysis. The use of this technique allows to understand the behavior of the universe under several circumstances. Apart from that we determine if trajectories in the proximity of a critical point are attracted or repelled by the point itself or, in other words, to study the stability properties of the critical point and acceleration phase of the universe which could then be analyzed with observational data.

308.03 — ΛCDM is in tension with Pantheon data at 4.3σ in ω_m

Maurice H. Van Putten[1]
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Surveys of the Local Universe show a Hubble expansion significantly greater than ΛCDM estimates from the Cosmic Microwave Background by Planck. We here report on a 4.3σ tension in $\omega_\mathrm{m} = \Omega_{m,0}$in Pantheon data, independent of Planck, observed in a novel probe over running intervals [0,z_max] ($0 < z_{max} < 2.26$). This tension reduces to 2.5σ in late time quantum cosmology, wherein de Sitter space is unstable by dark energy induced by the cosmological horizon with implied deviations from ΛCDM at the present epoch.

308.04 — A standard ruler at cosmic dawn

Julian B. Munoz[1]
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Dark matter and baryons posses supersonic relative velocities after recombination, as only the latter suffers baryon acoustic oscillations (BAOs). These velocities—imprinted with the acoustic scale in their genesis—impede the formation of the first stars during the cosmic dawn (z=20), modulating the expected 21-cm signal from this era, and inducing new velocity-induced acoustic oscillations (VAOs) in the 21-cm power spectrum. I will explain how to use these VAOs as a standard ruler at cosmic dawn, for which we take advantage of the immunity of VAOs to the unknown astrophysics of the first stars. I will show that the upcoming HERA interferometer will be able to measure the Hubble expansion rate H(z) at z = 17 – 21 to percent-level precision using VAOs.

308.05 — An interactionless Ising model for galaxy bias

Andrew Repp[1]
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Galaxy surveys, such as the upcoming Euclid and WFIRST missions, represent an important observational constraint on cosmology. However, the fact that galaxies are biased tracers of the underlying dark matter complicates the extraction of information from these surveys. In addition, the focus of current bias models is the high-density regions of the Universe, but low-density regions carry significant information relevant to dark energy and alternative gravitational theories. Thus it is necessary for a galaxy bias model to be accurate at both high and low densities. We here present such a model (inspired by the Ising model of ferromagnetism), and we demonstrate its good fit to both simulations and observational data. The quality of the fit indicates that, to a first approximation, galaxy formation is a local process determined by initial conditions.

308.06 — LISA for Cosmologists

Robert Caldwell[1]
[1] *Physics & Astronomy, Dartmouth College (Hanover, New Hampshire, United States)*

We survey the ability of the Laser Interferometer Space Antenna to address questions of cosmology. We present new results on Standard Siren tests of the cosmic expansion history at high redshift, and probes of the early Universe in the form of a stochastic gravitational wave background.

308.07 — Tachyon-Dominated Cosmology

Ian H. Redmount[1]
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Although tachyons—faster-than-light particles—are usually regarded as fanciful speculation, it is possible to construct a straightforward Einsteinian dynamics and thermodynamics governing such particles. The mass/energy density of a gas of "dark" tachyons is such that an open—spatially hyperbolic—Friedmann-Robertson-Walker spacetime dominated by such a gas can undergo the same large-scale evolution as the standard dark-energy/cold-dark-matter model: expansion from an initial singularity at a rate which decelerates to a minimum, passes through a "cosmic jerk," and subsequently accelerates. Features of such a model can be calculated and compared with observations. Of particular interest is the fact that the tachyon-dominated model asymptotically approaches a constant expansion rate and flat spacetime geometry, in contrast to the standard model, which expands exponentially in time and approaches de Sitter spacetime geometry. Hence, the two models might be distinguished either by grand-scale observations of the "jerk" of cosmic expansion, or by the quantum behavior of elementary-particle fields, or both.

308.08 — Ultra-High-Energy Cosmic Ray Acceleration by Hyper-Resistive Diffusion from Magnetic Tower Jets

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[2] *UC Berkeley (Berkeley, California, United States)*
[3] *Los Alamos National Laboratory (Los Alamos, New Mexico, United States)*

Accretion disk dynamo currents are shown to power relativistic jets in a two-quasi-steady-state model with hyper-resistive diffusion, in which a conical jet with $E_r = B_\varphi$ can be decelerated by the ambient medium to form a magnetic tower jet with j x B = 0. In the central column of the jet, the electron current is suppressed by a two-stream instability, and ions are preferentially accelerated over synchrotron radiating electrons. In the jet-lobe boundary, or nose, ions are further accelerated via drift cyclotron loss cone (DCLC) instability to the highest energies observed for cosmic rays (>0.1 ZeV). Other predictions of this model include: jet maximum length ($L = 10^{24}$ cm), width ($R = 0.1L$) and synchrotron luminosity ($P = 1.4\text{x}10^{43} M_8$ erg/s) and cosmic ray spectrum ($\sim E^{-3}$) and intensity (1/km^2 century) all concordant with observations from distant galaxies.

308.09 — Confirmation of Planet-Scale Astronomical Dark Matter in Extragalactic Systems

Saloni Bhatiani[1]*; Xinyu Dai*[1]*; Eduardo Guerras*[1]
[1] *Physics and Astronomy, University of Oklahoma (Norman, Oklahoma, United States)*

Quasar microlensing serves as a unique probe of discrete objects within galactic-scale lenses such as galaxies and galaxy clusters. Recent advancement of the technique shows that it can constrain planet-scale objects by studying their induced microlensing signatures, the energy shift of emission lines originated at the vicinity of the black hole of background quasars, beyond our native galaxy. We employ this technique to exert effective constraints on the sub-stellar mass distribution within two additional external lens systems, Q J0158–4325 ($z_l = 0.317$) and

SDSS J1004+4112 (z_l = 0.68) using Chandra observations of the two gravitationally-lensed quasars. The frequently observed variations of the emission line peak energy can be explained as microlensing of the FeKα emission region induced by planet-sized microlenses. To corroborate this, we perform microlensing simulations to determine the probability of a caustic transiting the source region and compare this with the observed line shift rates. Our analysis yields constraints on the sub-stellar population, with masses ranging from Moon (10^{-8} M⊙) to Jupiter (10^{-3} M⊙) sized bodies, within these galaxy-scale structures. Our results suggest that planet-scale astronomical dark matter is universal in external galaxies, and we surmise these objects to be either free-floating planets or primordial black holes. We present the first ever constraints on the sub-stellar mass distribution in the intra-cluster light of a galaxy cluster.

309 — Laboratory Astrophysics Division Meeting (LAD): Bridging Laboratory & Astrophysics: Molecules and Spitzer III

309.01 — LAD Dissertation Prize: Producing accurate theoretical anharmonic infrared cascade spectra of PAHs

Cameron J. Mackie[1]; Alessandra Candian[2]; Timothy J. Lee[3]; Alexander Tielens[2]

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[2] *Leiden Observatory (Leiden, Netherlands)*

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The infrared (IR) signatures of polycyclic aromatic hydrocarbons (PAHs) have been observed in numerous astronomical objects: from young stellar objects, to planetary nebulae, to the emissions of galaxies as a whole. Not only are these PAHs found in varied environments, their spectral features are likewise varied; indicating changes in properties such as size, structure, charge, temperature, hydrogenation, nitrogen substitutions, etc. Interpretation of these spectral features and their variations relies heavily on theoretical calculations. Until now, the majority of these theoretical IR spectra make use of scaled harmonic frequencies for band positions, and the double harmonic approximation for intensities. However, low-temperature high-resolution gas-phase experiments have shown that the harmonic treatment cannot reproduce experimental results reliably, especially in the C-H stretching region (~3.3 μm) and combination band region (~5 μm). In order to account for these deficiencies, anharmonic corrections need to be incorporated. Specifically, a second order vibrational perturbation theory approach is used in this work, which also takes into account the large number of vibrational resonances predicted for PAHs.

Additionally, the process in which PAHs absorb and emit energy in interstellar space is complex. PAHs are electronically excited by ultra-violet (UV) photons from a nearby star, then through an emissionless intraconversion process they drop to their electron ground state, and in doing so transfer the energy into their many vibrational modes. Then through a slow emission process, they emit this energy in the IR. This so-called cascade spectra results in an ever–changing internal vibrational energy (i.e., temperature) as the PAHs cool. Therefore, accurate calculations of anharmonic temperature effects are also required for every internal temperature visited during the cascade process. In this work we present a fully anharmonic IR cascade model (which includes recalculating resonances at each internal temperature), reproducing the actual type of PAH spectra which astronomers directly observe.

309.02 — Exploring Dust Composition in Debris Disks

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[3] *Far Eastern Federal University (Vladivostok, Russian Federation)*

Planetesimals left over from planet formation collide to generate dust around mature stars, observed as debris disks. The dust composition provides evidence for the material out of which planets form.

We are accumulating a wealth of debris disk imaging and spectroscopy: Hubble Space Telescope and ground-based adaptive optics imagers for for scattered light at visible to near-infrared wavelengths, Spitzer Space Telescope for mid-infrared spectrosocpy and Spitzer and Herschel for mid to far-infrared spectral distributions, and ALMA for submm emission from large grains observed at high angular resolution. The combination of data can be sensitive to important and astrobiologically relevant planetary constituents such as silicates (rock), water ice and carbonaceous compounds as well as grain size distributions related to the dynamics of the disk.

However, interpretation of scattered light and emission measurements simultaneously to provide unique constraints on the dust properties is difficult. The solution likely sits with new grain measurements and calculations.

As well as reviewing the field, I will show our new discrete dipole calculations made with the goals of creating grains that can both fit the scattered and thermal light, grains that include all major consituents in a more physical way than mixing theory, and grains that properly predict the measured phase functions of real particles and of debris disks. We are guided by interstellar and solar system dust analogs. Currently, we have a significant set of calculations for irregularly shaped particles both of homogeneous composition and of mixtures of astrosilicate with ice and carbonaceous components. We have investigated how our realistic morphologies affect the radiation pressure blowout sizes expected in debris disks and find a strong dependence.

We are also taking laboratory spectra and computing indices of refraction to extend the range of material available for debris disk modeling. Our measurements of an analog to meteoritic insoluble organic material show similarities to previously measured organics and are quite different from amorphous carbon or tholins.

309.03 — Dicarbon formation in collisions of two carbon atoms

James F. Babb[1]; *Ryan T. Smyth*[1,2]; *Brendan McLaughlin*[1,2]

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[2] *Queen's University Belfast (Belfast, Northern Ireland, United Kingdom)*

Radiative association cross sections and rates are computed, using a quantum approach, for the formation of C_2 molecules (dicarbon) during the collision of two ground state $C(^3P)$ atoms. We find that transitions originating in the C $^1\Pi_g$, d $^3\Pi_g$, and $1^5\Pi_u$ states are the main contributors to the process. The results are compared and contrasted with previous results obtained from a semi-classical approximation. New *ab initio* potential curves and transition dipole moment functions have been obtained for the present work using the multi-reference configuration interaction approach with the Davidson correction (MRCI+Q) and aug-cc-pCV5Z basis sets, substantially increasing the available molecular data on dicarbon. Applications of the current computations to various astrophysical environments and laboratory studies are briefly discussed focusing on these rates.

309.04 — Combined Experimental and Theoretical Study of Atomic Deuterium Reacting with H_3^+Isotopologues

Kyle Patrick Bowen[1]; *Pierre-Michel Hillenbrand*[1]; *Jacques Lievin*[3]; *Xavier Urbain*[2]; *Daniel Wolf Savin*[1]

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The partially deuterated isotopologues of H_3^+ (H_2D^+ and D_2H^+) play a prominent role in prestellar cores. At the typical densities and temperatures of prestellar cores, most species freeze onto dust grains. However, H_3^+ and its isotopologues remain in the gas-phase and become the dominant positive charge carriers. This affects the dynamics of core collapse through the coupling of the gas to any ambient magnetic fields. For this reason, knowledge of the total abundance of H_3^+ and its isotopologues is critical for modelling a core's evolution. The symmetric H_3^+ and D_3^+ do not have dipole moments, and therefore lack pure rotational spectra, rendering them unobservable at prestellar core temperatures. Determining the abundance of H_2D^+ and D_2H^+, which have pure rotational spectra that can be excited at prestellar core temperatures, allows for the total H_3^+ abundance to be inferred, provided the deuterating reactions of H_3^+ are well understood. Deuteration of H_3^+, H_2D^+, and D_2H^+ forming H_2D^+, D_2H^+, and D_3^+, respectively, can occur either in reactions with atomic D or with the diatomic molecules HD and D_2. The latter two cases are considered to be well understood through experimental and theoretical studies, and the results have been implemented into astrochemical models. In contrast, the role of deuteration through reactions with atomic D remains an open question. Currently, astrochemical models rely on theoretical classical rate coefficients for these reactions. Here, we present laboratory measurements of the rate coefficients for the reactions of atomic D with H_3^+, H_2D^+, and D_2H^+. The measurements were performed using a dual-source, merged fast beams apparatus. Co-propagating beams allow us to measure absolute total cross sections for relative collision energies between ~10 meV to ~10 eV . In addition, high-level quantum *ab initio* calculations have been carried out to model the zero-point-energy corrected energy profile and the shape of the potential energy barrier, allowing an evaluation of tunneling effects.

From the combination of our experimental and theoretical results, we derive thermal rate coefficients in the temperature range relevant for prestellar cores.

310 — Solar Physics Division Meeting (SPD), Flares III

310.01 — Probing the plasma sheet of the 2017 September 10 limb event using microwave spectroscopy

Dale E. Gary[1]; Bin Chen[1]; Gregory D. Fleishman[1]; Gelu M. Nita[1]; Sijie Yu[1]
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In its later phases, the 2017 Sep 10 X8.2 limb flare produced a dramatic, nearly radial plasma sheet that was the site of both bi-directional radial flows (inward and outward) and 100 km/s turbulent motions measured in highly ionized Fe lines (Warren et al. 2018). Below the plasma sheet is a dense set of post-reconnection flare loops whose upper loops emit strongly in thermal hard X-rays and hot EUV lines (T $\sim$ 20 MK), while the lower loops emit in much cooler lines such as Ca II (Kuridze et al. 2019). Observations of gyrosynchrotron emission from the Expanded Owens Valley Solar Array (EOVSA) show the presence of high-energy (> 300 keV) electrons at still higher heights above the EUV and hard X-ray loops. At microwave frequencies above about 14 GHz, EOVSA shows that the source shape is a nearly complete loop while at frequencies below about 10 GHz, the source is split into two lobes on either side of the plasma sheet. Using the spatially resolved EOVSA brightness temperature spectra, we investigate the cause of this bifurcated spatial structure. There are two competing possibilities for the "missing" emission at lower frequencies: (a) the emission may be absorbed by intervening high-density, relatively cool material in the plasma sheet or (b) the emission may be suppressed by the Razin effect due to a combination of hot high density material and low magnetic field strength. We use diagnostics from microwave imaging spectroscopy and AIA DEM analysis to determine the likely plasma parameters and other characteristics of the plasma sheet, and the relative placement of the microwave-emitting electrons and the plasma sheet along the line of sight.

310.02 — Hard X-ray emitting energetic electrons in connection with coronal EUV jets

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Flare-associated coronal EUV jets outline open magnetic field lines providing an escaping path to the interplanetary medium for particles accelerated during solar flares. Several studies have shown an observational link between coronal jets (observed in EUV or soft X-rays) and type III radio bursts, produced by escaping beams of energetic electrons, or in-situ energetic electron events. In a few events, coronal jets have also been associated with X-ray emitting energetic electrons during flares. However, the likelihood of the association of energetic electrons to coronal jets as well as the link between jet properties and hard X-ray emission properties has not been investigated on a large sample of events. We present here a statistical study of the link between X-ray emitting energetic electrons and the associated coronal EUV jets by looking at their relative timing, and their spatial and spectral characteristics. We observed non-thermal electrons in only 1/4 of the jets and only weak correlations between jets and flare properties. These results will be discussed in the context of jet modelling and particle acceleration and escape associated with coronal jets.

310.03 — Thermal and Nonthermal Evolutions of a Circular Ribbon Flare

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We studied the activation and the extended activity of a circular-ribbon flare, SOL2014-12-17T04:51 by performing the Differential Emission Measure (DEM) inversion analysis of the extreme ultraviolet (EUV) images of the Atmospheric Imaging Assembly (AIA) instrument onboard the Solar Dynamics Observatory (SDO) and analysis of the microwave data from the Nobeyama Radioheliograph (NoRH). We will present the following results. 1. The circular ribbon as an indicator of the dome-shaped separatrix is better visible in the preflare phase in the form of very narrow channel of enhance temperature. It is activated much earlier (10-15 min before the impulsive phase at 04:33 UT), and its temporal correlation with the outer spine temperature suggests the initial activation of the circular ribbon by magnetic reconnection in the outer spine. 2. The flare ribbons are active only within a limited section of the entire circular ribbon, suggesting the hyperbolic flux tube reconnection rather than null point reconnection. They are activated 4 min before the impulsive phase together with the inner spine, and involve nonthermal electrons as evidenced by the NoRH 34 GHz emission. 3. The temperature-high region and the DEM-high region coincide each other in the impulsive phase, and then separate from each other, implying that the rising magnetic fields carry hot plasma away while the high-density cooler plasma stays on the fan surface. 4. An unusually extended decay phase in this event can be understood as the maximum DEM in the impulsive phase occurs at a higher temperature and then gradually shifts to lower temperatures where EUV emission is more efficient. Namely, the extended EUV activity is due to slow cooling of the hot plasma within the confined magnetic structure.

310.04 — Magnetohydrodynamic Simulation of Magnetic Null-point Reconnections and Coronal dimmings in NOAA AR 11283

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The magnetohydrodynamics of active region NOAA 11283 is simulated using an initial non-force-free magnetic field, extrapolated using the photospheric vector magnetogram of the active region. Particularly, we focus on the magnetic reconnections (MRs) occurring close to a magnetic null point that resulted in the X2.1 flare on 2011 September 06 around 22:12 UT followed by the appearance of circular chromospheric flare ribbons and coronal dimming. Importantly, the extrapolated initial non-force-free field shows the presence of a twisted flux rope near the polarity inversion line and a three-dimensional (3D) null situated near one of the major polarities. In the simulated dynamics, we find MRs occurring below the rope that leads to an increase in the twist and consequent rise of the flux-rope. As one end of the rising rope approaches the 3D null point, reconnections ensue – leading to the main flare and the subsequent formation of circular flare ribbons. Interestingly, the MRs open up the flux-rope that can potentially lead to the loss of plasma confined in the rope and provide a viable explanation for coronal dimming and jet-like eruptions. Furthermore, the location of the footpoints of the rope during the reconnections are found to be in good correlation with the dimming regions inferred from Extreme-Ultraviolet images observed after the flare.

310.05 — Radiative MHD Simulation of a Solar Flare

Mark Cheung[1]; Matthias D. Rempel[2]; Georgios Chintzoglou[1]; Feng Chen[2]; Paola Testa[3]; Juan Martinez-Sykora[1]; Alberto Sainz Dalda[1]; Marc L. DeRosa[1]; Anna Malanushenko[2]; Viggo Hansteen[4]; Mats Carlsson[4]; Bart De Pontieu[1]; Boris Gudiksen[4]; Scott W. McIntosh[2]

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We present a radiative MHD simulation of a solar flare. The computational domain captures the near-surface layers of the convection zone and overlying atmosphere. Inspired by the observed evolution of NOAA Active Region (AR) 12017, a parasitic bipolar region is imposed to emerge in the vicinity of a pre-existing sunspot. The emergence of twisted magnetic flux generates shear flows that create a pre-existing flux rope underneath the canopy field of the sunspot. Following erosion of the overlying bootstrapping field, the flux rope erupts. Rapid release of magnetic energy results in multi-wavelength synthetic observables (including X-ray spectra, narrowband EUV images, Doppler shifts of EUV lines) that are consistent with flare observations. This works suggests the super-position of multi-thermal, superhot (up to ~100 MK) plasma may be partially responsible for the apparent non-thermal shape of coronal X-ray sources in flares. Implications for remote sensing observations of other astrophysical objects is also discussed. This work is an important stepping stone toward high-fidelity data-driven MHD models.

310.06 — Multi-wavelength Investigation of Energy Release and Chromospheric Evaporation in Solar Flares

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For understanding of energy release and chromospheric evaporation in solar flares it is necessary to perform a combined multi-wavelength analysis of observations from space- and ground-based observatories and compare the results with predictions of the radiative hydrodynamic (RHD) flare models. The case study of spatially-resolved chromospheric evaporation for an M1.0-class solar flare using data form IRIS, HMI/SDO, and VIS/GST, demonstrated a complicated nature of evaporation and its connection to the magnetic field topology. Following this study, the Interactive Multi-Instrument Database of Solar Flares is designed for efficient search, integration, and representation of flares for statistical studies. Comparison of the energy release and chromospheric evaporation properties for seven solar flares simultaneously observed by IRIS and RHESSI with predictions of the RHD electron beam-heating flare models revealed weak correlations between deposited energy fluxes and Doppler shifts of IRIS lines for observations and strong for models, together with other quantitative discrepancies. Statistical analysis of Soft X-Ray (SXR) emission, plasma temperature (T), and emission measure (EM) properties derived from GOES observations demonstrated that flares form two groups, "T-controlled" and "EM-controlled", distinguished by contribution of T and EM to the SXR peak formation and presumably evolving in loops of different lengths. Modeling of the SDO/HMI LOS observables for RHD flare models highlights that for high deposited energy fluxes ($\geq 5\times10^{10}$ erg cm^{-2}s^{-1}) the sharp magnetic transients and Doppler velocities observed during the solar flares by HMI should be interpreted with caution. Finally, the flare prediction problems and the role of the magnetic field Polarity Inversion Lines (PIL) in the initiation and development of flares are considered. The possibility to enhance the operational forecasts of M-class flares by considering jointly PIL and other magnetic field and SXR characteristics is demonstrated, with corresponding Brier Skill Score (BSS=0.29±0.04) higher than for the SWPC NOAA operational probabilities (BSS=0.09±0.04).

311 — Solar Physics Division Meeting (SPD), DKIST II

311.01 — Chromospheric Evaporation Observed in an Isolated Magnetic Flux Tube

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[1] *NJIT (Newark, New Jersey, United States)*

We study chromospheric evaporation of an isolated magnetic flux tube, with IRIS, SDO and BBSO/GST observations. During the initial phase of an M6.5 flare on 2015-06-22, two isolated emission patches are visible prior merging with the main flare ribbons. These two point sources are characterized with central reversals and significantly broadened Mg II k/h and C II Å lines, (with a FWHM of 1.6 Å and 0.8 Å, respectively), respectively, likely due to turbulences. The Doppler shifts of optically thin lines, Si IV 1402.77 Å and Mg II 2791.59 Å, suggest upflows about 26 km/s and 2 km/s, respectively. A stand-alone EUV loop, connecting the two stationary flare footpoints, is identified by SDO/AIA images and confirmed by the coronal magnetic field extrapolated from the SDO/HMI magnetograms. The temporal variation of the intensity and differential emission measure of the two brightenings show obvious delay, about 2-3 minutes, indicating localized reconnection and heating. In contrast, on the main flare ribbon, the Si IV line shows obvious downflows with a speed of 38 km/s. The different behavior of the flare ribbon and isolated footpoints is possibly due to the different heating magnitudes and altitudes.

311.02 — Evolution of bipolar internetwork magnetic fields

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Internetwork (IN) magnetic fields can be found inside supergranular cells all over the solar surface. Thanks to their abundance and appearance rate, IN fields are considered to be an essential contributor to the magnetic flux and energy budget of the solar photosphere, and may also play a major role in the energy budget of the chromosphere and transition region. Therefore, it is crucial to understand how IN magnetic fields appear, evolve, interact with the preexisting magnetic structures, and what impact they have on the upper solar atmosphere. Here, we analyze spatio-temporal evolution of IN magnetic bipolar structures, i.e, loops and clusters, employing multi-instrument (IRIS and SST), multi-wavelength observations of IN regions with the highest sensitivity and resolution possible. For the first time, our observations allow us to describe in detail how IN bipoles emerge in the photosphere and even reach the chromosphere. We estimate the field strengths of these IN magnetic structures both in the photosphere and the chromosphere, using full Stokes measurements in Fe I 6173 Å, Mg I b_2 5173 Å, and Ca II 8542 Å. Employing the IRIS FUV and NUV spectra, we show that IN fields contribute to the chromospheric and transition region heating through interaction with the preexisting ambient fields.

311.03 — Disentangling Chromospheric Temperatures and Dynamics with ALMA and IBIS

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The chromosphere is highly structured in density, dynamics, and temperature. Unfortunately, it can be difficult to disentangle the different contributions of these physical conditions to our current set of observable diagnostics. With the advent of high-resolution observations of the millimeter continuum with the Atacama Large Millimeter Array (ALMA), we have a new tool to probe the chromospheric temperature structure. By combining these observations with similar observations in other visible, infrared, and UV lines, we are better able to disentangle the thermal and dynamical behavior of the chromosphere. In this talk, we discuss the results of combining ALMA images with imaging spectroscopy from the Interferometric Bidimensional Spectrometer (IBIS). We find evidence that spectral-line parameters of Hα and Ca II are closely correlated with the ALMA brightness temperatures. We have performed spectral inversions employing multiple diagnostics to retrieve typical atmospheric conditions in our field of view. We discuss how this joint analysis changes our understanding of chromospheric dynamics and the interpretation of the observed spectral intensities. Finally, we explore how these results can guide future observations of the chromosphere from both ALMA and DKIST.

311.04 — Magnetic Field Dynamics and Varying Plasma Emission in Large Scale Coronal Loops

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We report detailed observations of magnetic environment at four footpoints of two warm coronal loops observed on 5 May 2016 in NOAA AR 12542 (Loop I) and 17 Dec 2015 in NOAA AR 12470 (Loop II). These loops were connecting a plage region with sunspot periphery (Loop I) and a sunspot umbra (Loop II). We used Solar Dynamics Observatory (SDO) and Goode Solar Telescope (GST) data to describe the phenomenon and understand its causes. The study indicates loop brightening episodes were associated with magnetic flux emergence and cancellation processes observed in SDO's Helioseismic and Magnetic Imager (HMI) and GST's Near InfraRed Imaging Spectrapolarimeter (NIRIS) data. The observed activity was driven by magnetic reconnection between small-scale emerging dipoles and large-scale pre-existing fields, suggesting that the reconnection occurred in the lower chromosphere at the edge of an extended plage region, where the loops were rooted. We suggest that plasma, evaporated during these reconnection events, gradually filled the loops and as it cooled the visible density front propagated from one footpoint of the loop to another at a rate of 90-110 km/s. This study also indicates that at least some of the bright loops seen in SDO Atmospheric Imaging Assembly images rooted in sunspot umbra may be heated due to magnetic activity taking place at the remote (non-sunspot) footpoint.

312 — Plenary Lecture: Cosmological Inference from Large Galaxy Surveys, Elisabeth Krause (University of Arizona)

312.01 — Cosmological Inference from Large Galaxy Surveys

Elisabeh Krause[1]
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The accelerated expansion of the Universe is the most surprising cosmological discovery in decades. It has inspired a new generation of ambitious surveys to determine the fundamental nature of this acceleration. I will introduce the different measurement techniques used by today's cosmologists, describe the landscape of current and near future wide-field galaxy surveys, and present cosmology constraints from the Dark Energy Survey (DES Y1). This analysis constrains the composition and evolution of the Universe through a combination of galaxy clustering,

galaxy-galaxy lensing, and cosmic shear. These three measurements yield consistent cosmological results, and in combination they provide some of the most stringent constraints on cosmological parameters. I will describe the validation of measurements and modeling from pixels to cosmology and I will give an outlook on cosmology analysis plans and challenges for future, much larger experiments such as LSST and WFIRST.

314 — Laboratory Astrophysics Division Meeting (LAD): Bridging Laboratory and Astrophysics: Exoplanets III

314.01 — The ExoMol project: molecular line lists for the opacity of exoplanets and other hot atmospheres

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The ExoMol project provides molecular line lists for exoplanets and other atmosphere with a particular emphasis on those atmospheres which are significantly hotter than the Earth's. ExoMol has now computed line lists for over 40 molecules including, in most cases, isotopologues. These are available at www.exomol.com. Key new ine lists include ones for TiO, H_3^+, NO, C_2H_4 and a significantly improved one for hot water, as well as for a range closed and open shell diatomic molecules.

Fundamental molecular data play a key role for spectral characterization of astrophysical objects cool enough to form molecules in their atmospheres (cool stars, extrosolar planets and planetary discs) as well as in a broad range terrestrial applications. However, at elevated temperatures, the laboratory data for a number of key species is absent, inaccurate or incomplete. The ExoMol project provides comprehensive line lists with the aim of providing data for all molecules likely to be observable in exoplanet atmospheres in the foreseeable future. This is a huge undertaking which involves providing in excess of a hundred of billion spectral lines for a large variety of molecular species.

The ExoMol database had a formal release in 2016; it provides information on a variety of topics including, of course, line lists, cross sections (generated from the same line lists), lifetimes and Landé g-factors. It comprises 52 molecules (130 isotopologues). Our new flexible code ExoCross can rapidly generate cross sections even from huge line lists. ExoCross also allows facile conversion between ExoMol and HITRAN formats. Work is in progress to provide high accuracy transition frequencies for use in high resolution studies of exoplanets. A formal implementation of this will form part of the 2020 ExoMol release.

314.02 — Latest updates to the CHIANTI atomic database

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CHIANTI is a database of atomic data parameters and a software package for computing the radiative emissions from optically-thin astrophysical plasmas. CHIANTI is freely available to the community (http://chiantidatabase.org), and is very widely used in the Heliophysics and Astrophysics communities. The papers describing CHIANTI have been cited over 3500 times in the 22-year lifetime of the project.

Version 9 of CHIANTI was released in March 2019, and this presentation summarizes the new updates and highlights important applications. The key change for CHIANTI 9 was the implementation of a new method to account for recombination and dielectronic capture in the level balance equations through new, two-ion models that fully capture the state-to-state transitions between ions. The models are needed for the calculation of X-ray satellite lines and, for the first time, enable density sensitivity to be modeled.

A number of the standard atomic data-sets have been updated, including recombination rates for several important coronal iron ions. New software routines have been written for computing the differential emission measure of a plasma, and for computing the response functions of the Atmospheric Imaging Assembly on board NASA's Solar Dynamics Observatory .

314.03 — Lifetimes, Branching Fractions, and Oscillator Strengths for Ultraviolet Transitions in P II and Cl I

Steven Robert Federman[1]; Rabee Alkhayat[1]; Michael Brown[1]; Negar Heidarian[1,2]; Richard Irving[1]; Jeremy Bancroft Brown[1]; Song Cheng[1]; Larry Curtis[1]; David Ellis[1]

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[2] *Univ. of Maryland (College Park, Maryland, United States)*

Observations of absorption from ultraviolet transitions of atomic species in diffuse interstellar clouds provide data on elemental gas phase abundances. From this information the level of depletion onto interstellar grains, the nucleosynthetic pathways for the element, and the chemistry involving the element can be inferred. Here we describe results on P II and Cl I from beam-foil measurements with the Toledo Heavy Ion Accelerator that build on our earlier efforts on P II λ1153 and Cl I $\lambda\lambda$1088, 1097, 1347. In particular, lifetimes, branching fractions, and the associated oscillator strengths (f-values) for the P II multiplet at 1308 Å and for Cl I lines at 1004, 1079, 1090, and 1095 Å were obtained. Contamination from P I and P IV emission had to be removed for an accurate set of P II branching fractions. Our results for the suite of transitions in P II and Cl I agree very well with the data obtained from recent theoretical calculations, and our f-values for the Cl I lines confirm the values inferred from spectra acquired with the *Far Ultraviolet Spectroscopic Explorer*. Future analyses of interstellar P and Cl abundances can be placed on a more secure footing.

314.04 — Relativistic Atomic Structure of the Au III Isoelectronic Sequence: opacity data for kilonova ejecta

Yier Wan[1]; Z. S. Taghadomi[1]; A. Flowers[1]; Phillip C. Stancil[1]; Brendan M. McLaughlin[4]; S. Loch[2]; S. Bromley[3]; J. P. Marler[3]; C. E. Sosolik[3]

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The detection of a neutron star merger (NSM) event and the spectral observation of its optical and infrared emission opens up the possibility of direct interrogation of the formation site of heavy r-process elements. However, laboratory spectroscopic data for the vast range of heavy elements are severely limited. The current focus is on one of the "second peak" elements - gold. Two General Relativistic Atomic Structure Packages, Grasp0[1, 4] and Grasp2K[2], are used to obtain the level energies and transition probabilities. Here, Au III, as well as its low-charged isoelectronic sequence members, Ir I, Pt II, and Hg IV, are computed and compared against available theoretical and experimental data[3]. The Au III results are used to simulate the emission spectrum to interpret the Compact Toroidal Hybrid experiment with a gold-plated probe. This work was partially supported by NSF grant 1816984.

[1] Dyall, et al., Computer physics communications, 55(3):425–456, 1989. [2] Per Jonsson, et al., Computer Physics Communications, 184(9):2197–2203, 2013. [3] Kramida, et al. NIST Atomic Spectra Database, https://physics.nist.gov/asd [4] Parpia, et al., Computer physics communications, 94(2-3):249–271, 1996

315 — WFIRST Ultra-Deep Fields II

315.01 — Deep Grism/Prism observations with WFIRST

Sangeeta Malhotra[1]

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Multiple projects on HST have shown the usefullness of deep slitless grism spectroscopy. The main advantage is to get spectra of everything in an unbiased way. This has led to studies of emission line dominated galaxies, which would not make the spectroscopy cut on the basis of continuum brightness alone. These are low mass, low metallicity starburst galaxies. Even without emission lines these spectra can be used to improve and calibrate photometric redshifts. Deep spectroscopy observations by WFIRST can provide a few 100,000 redshifts per WFIRST field, including those of Lyman-α and Lyman Break galaxies in the epoch of reionization.

315.02 — Deep Fields, PFS, and Other Spectroscopic Surveys

Rachel Bezanson[1]

[1] *University of Pittsburgh (Pittsburgh, Pennsylvania, United States)*

I will discuss existing and planned spectroscopic surveys in the context of ancillary datasets in potential WFIRST deep fields. In particular, I will focus on the wide field PFS galaxy evolution spectroscopic survey - describing the multi-wavelength photometric data and optical/NIR spectroscopic targeting strategies and anticipated data quality.

315.03 — Constraining the Evolution of Reionization with US-ELT Followup of WFIRST Deep Drilling Fields

Steven L. Finkelstein[1]
[1] *University of Texas (Austin, Texas, United States)*

The epoch of reionization ($6 < z < 10$) marks the period in our universe when the first large galaxies grew to fruition, and began to affect the universe around them. Massive stars, and potentially accreting supermassive black holes, filled the universe with ionizing radiation, burning off the haze of neutral gas that had filled the intergalactic medium (IGM) since recombination ($z \sim 1000$). The evolution of this process constrains key properties of these earliest luminous sources, thus observationally constraining reionization is a key science goal for the next decade. The measurement of Lyα emission from photometrically-identified galaxies is a highly constraining probe of reionization, as a neutral IGM will resonantly scatter these photons, reducing detectability. While significant work has been done with 8–10m telescopes, *these observations require extremely large telescopes* (ELTs) – the flux limits available from today's 10m class telescopes are sufficient for only the brightest known galaxies ($m < 26$). Ultra-deep surveys with the Giant Magellan Telescope (GMT) and Thirty Meter Telescope (TMT) will be capable of detecting Lyα emission from galaxies 2-3 magnitudes fainter than today's deepest surveys. Wide-field fiber spectroscopy on the GMT combined with narrow-field AO-assisted slit spectroscopy on the TMT will be able to probe the expected size of ionized bubbles throughout the epoch of reionization, following up ~degree scale deep imaging surveys with the *Wide Field Infrared Space Telescope*. These data will provide the first resolved Lyα-based maps of the ionized intergalactic medium throughout the epoch of reionization, constraining models of both the temporal and spatial evolution of this phase change.

315.04 — Modeling the Sky with All Available Data

Peter Melchior[1]
[1] *Princeton University (Princeton, New Jersey, United States)*

The image modeling framework "SCARLET" (Melchior et al. 2018) enables the joint use of multiple data sets of the same celestial scene. It improves source modeling and source separation by working on multi-band and images and by combining images of different resolution (both spatially and spectrally). It is specifically developed for joint pixel-level processing of data from LSST, WFIRST, and Euclid and leverages their imagers and grism spectrographs. I will introduce the method, discuss the statistical challenges in interpreting scenes consistently across multiple data sets, and demonstrate the improvement for precision measurements and astrophysical modeling that are achievable with SCARLET.

316 — ISM & The Milky Way

316.01 — Critical Ionization Velocities in Interstellar Space: An Introduction

Gerrit L. Verschuur[1]
[1] *Unaffiliated (Sunnyvale, California, United States)*

The critical ionization velocity (CIV) is a well-studied plasma phenomenon where atoms become ionized in the presence of a magnetic field when their kinetic energy relative to plasma is equivalent to their ionization potential. This effect has been observed in the laboratory and in near-earth space and is the subject of an extensive literature. We will briefly outline the process by which ionization is facilitated. The signature of this effect is found in the component structure of interstellar neutral hydrogen emission profiles obtained as part of the GALFA HI Survey. This is dramatic confirmation of similar results based on analysis of earlier studies of HI profiles obtained with other telescopes. The CIV phenomenon, mediated by plasma instabilities, may act as a major source of energy in the interstellar medium, a conclusion that has far-reaching consequences for our understanding of interstellar physics.

316.02 — Hydrogen, Helium, and Magnetic Fields in Interstellar Space

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[1] *USRA (Columbia, Maryland, United States)*
[2] *Unaffiliated (None, California, United States)*

Analysis by multiple authors of a variety of interstellar neutral hydrogen features studied over many decades using data from different telescopes reveals a pervasive 34 km/s wide component. The traditional explanation, that the line width results from a kinetic temperature, would mean that T = 24,000 K, high enough to ionize the gas so it could not contribute to the 21-cm profile. Turbulent motions could explain a pervasive broad component, but not why it has the same numerical value in so many different types of HI features. Confusion due to telescope side lobes has been proposed as a possible explanation, but the broad feature persists in side-lobe-corrected survey data. The critical ionization velocity is a well-studied plasma phenomenon where atoms become ionized in the presence of a magnetic field when their kinetic energy relative to the plasma is equivalent to the ionization potential. The critical ionization velocity for helium is 34 km/s, which could account for the pervasiveness of this component. This result supports other evidence that the neutral hydrogen in the interstellar medium is tightly coupled to the galactic magnetic field (Clark et al. 2014; 2015). Strong support for this interpretation stems from the resulting abundance of interstellar helium, which can be estimated from the column density fraction of the 34 km/s component with respect to the entire emission profile. A derived value of 0.28 is within one σ of the cosmic abundance of helium.

316.03 — Anchoring Magnetic Fields in Turbulent Molecular Clouds. II. From 0.1 to 0.01 pc

Yapeng Zhang[1]
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We compared the magnetic field directions inferred from polarimetry data obtained from 100 pc scale inter-cloud media (ICM) and from subparsec scale molecular cloud cores. The highly correlated result led us to conclude that cloud turbulence must be sub-Alfvénic. Here we extend the study with 0.01 pc cores observed by interferometers. The inferred field directions at this scale significantly deviate from that of the surrounding ICM. An obvious question to ask is whether this high-resolution result contradicts the sub-Alfvénic picture concluded earlier. We performed MHD simulations of a slightly super-critical (magnetic criticality = 2) clouds with Alfvénic Mach number M_A= 0.63 ($M_A \equiv < \sigma_V / V_A >$, where σ_V and V_A are, respectively, local 3D velocity dispersion and Alfvén velocity; < ... > means the average within the entire simulated volume; e.g., Burkhart et al. 2009), which can reproduce the Paper I results, and observed the development toward smaller scales. Interestingly, all subregions hosting cores with $n(H_2) > 10^5$/cc (the typical density observed by interferometers) possess M_A = 2–3. Not too surprisingly, these slightly super-Alfvénic cores result in B-field orientation offsets comparable to the interferometer observations. The result suggests that gravity can concentrate (and maybe also contribute to, which requires further study to confirm) turbulent energy and create slightly super-Alfvénic cores out of sub-Alfvénic clouds. The results of our simulations also agree with the observed velocity-scale, mass-scale, and field-density relations.

316.04 — On the Breakthrough Listen Search for Signs of Intelligent Life Near the Galactic Center

Vishal Gajjar[1]*; Andrew Siemion*[1]*; Steve Croft*[1]*; David R. DeBoer*[1]*; J. Emilio Enriquez*[1]*; Howard T. Isaacson*[1]*; Matt Lebofsky*[1]*; David MacMahon*[1]*; Daniel Price*[1]*; Dan Werthimer*[1]
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Over the last decade, discoveries of numerous earth type exoplanets have extended the possibility of other life-bearing worlds. However, the question of the existence of intelligent life might remain elusive unless a dedicated attempt is made to extensively Search for Extra-Terrestrial Intelligence (SETI). The Breakthrough Listen (BL) is a 10-year effort to conduct the most sensitive, comprehensive, and intensive search for advanced intelligent life on other worlds ever performed. The Galactic Center (GC) is a key observational target for the radio component of the BL program. The line of sight toward the GC offers the largest integrated galactic star count of any direction in the sky, is a widely cited possible location for beacon builtby an advanced intelligence and is the most energetic region in the Milky Way. Given the potential for discovery in the GC region, the BL survey will cover the entire frequency range from 700 MHz to 100 GHz using the Green Bank Telescope (GBT) and Parkes Telescope. We plan to conduct deep observations of around 350 hours from the GBT and 280 hours from the Parkes telescope; making it the most significant SETI survey to date of any region of the sky. The GC region is also an exciting observational target for a host of natural astrophysical phenomena, prominently including pulsars in close orbits around the central super-massive black hole, Sgr A, or in new exotic systems such as a millisecond pulsar in a binary system with a black hole. Other astrophysics of interest include accelerated masers, spectral line surveys, and studies of the detailed structure of the dense ionized Interstellar Medium (ISM) in the GC. I will review these observation strategies and novel data analysis techniques we plan to deploy to investigate a range of signal types using state-of-the-art machine learning tools.

316.05 — The Spiral Magnetic Field in the Central 5 Parsecs of the Galaxy

C. Darren Dowell[1]; David T. Chuss[2]; Jordan A. Guerra[2]; Martin Houde[3]; Joseph M. Michail[2]; Mark Morris[4]; Joan T. Schmelz[5]; Johannes Staguhn[6,7]; Michael W. Werner[1]

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At $\lambda \approx 50$ microns, the most prominent feature in the inner parsecs of the Milky Way is the rotating, irregular Circum-Nuclear Ring (CNR) which demarcates the inner boundary of the molecular gas that is likely spiraling in toward the supermassive black hole. The gas is magnetized, with previous estimates of field strength exceeding 1 milliGauss. We present new observations of the polarization and inferred magnetic field structure of the CNR and vicinity, made at λ = 53 microns with the HAWC+ instrument on SOFIA. These observations show a spiral magnetic field on scales of 0.5 - 5 pc, with organized components, but mostly lacking the 180 degree symmetry of existing magnetized accretion disk models. We discuss estimates of the magnetic field strength from the 53 micron data, the relationship of these data to observations at shorter and longer far-infrared wavelengths, and interpretation of several of the magnetic features observed.

316.06 — A Radial Velocity Survey of Embedded Sources in the Rho Oph Molecular Core

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We present the results of a radial velocity survey of young stellar objects in early stages of evolution in the core of the L 1688 molecular cloud. New and archival spectra obtained with four high resolution infrared spectrographs were analysed using Markov Chain Monte Carlo techniques that simultaneously fit for the radial velocity, Teff, vsini, and veiling by comparison with synthetic spectra. The radial velocity distribution for 32 objects, most with Class I or Flat-spectrum spectral energy distributions, is marginally gaussian, with a higher dispersion relative to optical surveys at the 2 σ level. When comparing the results from both proper motion and radial velocity surveys in L 1688, there is a trend for the 1-D dispersions to be higher for samples of Class I/Flat-spectrum young stellar objects that reside in the cloud core compared to Class II/III dominated samples which are located in the lower extinction periphery. In addition, there is a velocity gradient along the major axis of the cloud core that appears more pronounced than that derived from optically visible objects at the cloud edges. If these higher dispersions for Class I/Flat-spectrum objects are confirmed by future surveys, this could imply a supervirial state for the less evolved objects in the cloud core and be a signature of the initial collapse and rebound of the cluster as suggested by recent simulations of cluster evolution.

317 — Solar Physics Division Meeting (SPD), Eruptions

317.01 — A Two-Sided-Loop X-Ray Solar Coronal Jet and a Sudden Photospheric Magnetic-field Change, Both Driven by a Minifilament Eruption

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Most of the commonly discussed solar coronal jets are of the type consisting of a single spire extending approximately vertically from near the solar surface into the corona. Recent research shows that eruption of a miniature filament (minifilament) drives at least many such single-spire jets, and concurrently generates a miniflare at the eruption site. A different type of coronal jet, identified in X-ray images during the Yohkoh era, are two-sided-loop jets, which extend from a central excitation location in opposite directions, along two opposite low-lying coronal loops that are more-or-less horizontal to the surface. We observe such a two-sided-loop jet from the edge of active region (AR) 12473, using data from

Hinode XRT and EIS, and SDO AIA and HMI. Similar to single-spire jets, this two-sided-loop jet results from eruption of a minifilament, which accelerates to over 140 km/s before abruptly stopping upon striking overlying nearly-horizontal magnetic field at ~30,000 km altitude and producing the two-sided-loop jet via interchange reconnection. Analysis of EIS raster scans show that a hot brightening, consistent with a small flare, develops in the aftermath of the eruption, and that Doppler motions (~40 km/s) occur near the jet-formation region. As with many single-spire jets, the trigger of the eruption here is apparently magnetic flux cancelation, which occurs at a rate of $\sim 4 \times 10^{18}$ Mx/hr, comparable to the rate observed in some single-spire AR jets. An apparent increase in the (line-of-sight) flux occurs within minutes of onset of the minifilament eruption, consistent with the apparent increase being due to a rapid reconfiguration of low-lying magnetic field during the minifilament eruption. Details appear in Sterling et al. (2019, ApJ, 871, 220).

317.02 — New Insights into the 10 September 2017 Mega-Eruption

Judith T. Karpen[1]; Pankaj Kumar[3]; Spiro K. Antiochos[1]; Dale E. Gary[2]; Joel Dahlin[3]
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The X8.2 flare on 10 September 2017 was part of a well-observed, extremely energetic solar eruption that has been intensely studied. Much attention has been devoted to the striking appearance and persistence of a current sheet behind the explosively accelerating CME. We focus here on the unusual appearance of prominent emission features on either side of the flare arcade, which were detected in microwave emissions by NJIT's EOVSA before the peak impulsive phase. Our analysis combines the results of 3D numerical simulations with observations by SDO, EOVSA, and IRIS to decipher the underlying magnetic structure of the erupting region and the initiation mechanism. The event originated in a complex active region with a large-scale quadrupolar magnetic field punctuated by many intrusions of minority polarity. We interpret the observed microwave features as evidence of electron acceleration due to breakout reconnection, and present compelling evidence for this conclusion.

317.03 — STITCH: A New Method for Generating Filament Channels and Driving Solar Eruptions

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[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

We present a new formalism for generating eruptive magnetic structure in MHD simulations of the solar corona. STITCH (STatistical InjecTion of Condensed Helicity) derives from the helicity condensation model of Antiochos (2013). In the helicity condensation model, small-scale photospheric convection drives a reconnection-mediated inverse cascade that concentrates energy and structure to form highly sheared filament channels.Our recent 3D MHD calculations using more than 100 cyclonic surface flows have demonstrated explosive solar eruptions driven by helicity condensation. However, this manner of direct calculation of small-scale flows and the resulting reconnection is prohibitively expensive for use in data-driven event modeling or long-duration magnetofrictional studies of the global solar magnetic field (Mackay et al. 2014, 2018). Our new method, STITCH, directly injects the tangential field (shear) resulting from statistically averaged, sub-grid helicity condensation. Numerically, this represents a source term in the induction equation, consisting of the curl of the vertical field times a factor proportional to the cyclonic specific angular momentum - a single free parameter. The new approach reproduces prior calculations with small-scale flows at greatly reduced computational expense. We present a variety of simulations with complex initial flux distributions to demonstrate the flexibility of the model. STITCH is both simple to implement and computationally inexpensive, making it a useful new technique for event-based and data-driven modeling of solar eruptions. This work was supported by the NASA LWS, NPP, H-SR and ISFM programs.

317.04 — Bounding the Energy of Solar Eruptions

Jon A. Linker[1]; Cooper Downs[1]; Ronald M. Caplan[1]; Tibor Torok[1]; Pete Riley[1]; Viacheslav Titov[1]; Roberto Lionello[1]; Zoran Mikic[1]; Tahar Amari[1]
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Major solar eruptions such as X-class flares and coronal mass ejections (CMEs) are the fundamental source of solar energetic particles and geomagnetic storms, and are thus key drivers of space weather at Earth. The energy for solar eruptions is recognized to originate in the solar magnetic field, and is believed to be stored as free magnetic energy (energy above the potential field state) prior to eruption. Solar active regions are the site of the most violent activity. Solar active regions can store widely varying amounts of energy, so knowledge of the free energy alone does not necessarily tell us when an eruption is imminent. For estimates of the free energy to provide predictive power, we must know how much energy a region can store - what is the energy bound?

In recent work, we have found that the energy of a particular field, the partially open field (POF), can place a useful bound on the energy of an eruption from real active regions, a much tighter constraint than the energy of the fully open field. However, in general, it is difficult to solve for the POF. In this presentation, we discuss methods for approximating the energy of this field, and show a comparison of the approximation for a case where the solution is known. We discuss the implications for understanding and predicting major solar eruptions.

Research supported by NASA and AFOSR

317.05 — Improving Forecasting of Drivers of Severe Space Weather with the New MAG4 HMI Vector Magnetogram Database

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Major solar flares and Coronal Mass Ejections (CMEs) are drivers of severe space weather. The strongest ones come from active regions (ARs). They are powered by explosive release of magnetic energy. MAG4 (Magnetogram Forecast) is a large-database near-real-time tool that measures an AR's free-energy proxy from the AR's deprojected HMI vector magnetograms. MAG4 converts the free-energy proxy to the AR's predicted event rate (and event probability) using a forecasting curve. MAG4 forecasts the event rate and probability for each AR on the disk, as well as for the full disk. The forecasting curves presently used by MAG4 are derived from a large sample of SOHO/MDI AR magnetograms. This requires the HMI vector magnetograms to be degraded in spatial resolution to approximate what MDI would have measured, in order to use the MDI forecasting curves. We report on the improved performance of MAG4 that results from using forecasting curves based on MAG4's new database of HMI vector magnetograms instead of using the present forecasting curves that are based on MDI line-of-sight magnetograms. MAG4's forecasting skill score significantly improves for major flares (M1 or greater). We present MAG4's improvement in forecasting SPEs (Solar Particle Events) and X-class flares as well. The improvement in forecasting CMEs will be evaluated in the future. These new forecasting curves are being implemented in the near-real-time operational MAG4, though forecasts from the old curves will still be given. This work is funded by NSF's Solar Terrestrial Program, and NASA/SRAG.

317.06 — A statistical study of magnetic flux ropes in the solar active region with strong non-neutralized current

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Recent studies suggest non-neutralized electric current in the active region may relate to the solar eruptions. Our previous studies show that the footpoints of the pre-existing magnetic flux rope (MFR) is co-spatial with strong non-neutralized current, while the in-situ formed MFR is not. These results imply that strong non-neutralized current in the MFR's feet may relate to the eruptions. In this study, we intend to test whether strong current will be one signature of pre-existing MFRs and whether it relate to the eruptions. We investigate 10 active regions with strong non-neutralized currents. All active regions are characterized by strong shear motions or sunspot rotations. We found 13 MFRs, which appear as expanding structures, filaments, sigmoids, or hot channels before/during their eruption. The footpoints of MFRs are identified unambiguously with conjugate coronal dimmings. The results show that the MFRs with clear pre-eruption dimmings are co-spatial with strong currrents. However, half of MFRs only with post-eruption dimmings are not in strong currents regions. We also found most pre-eruption dimmings are co-spatial with sunspot rotation, while post-eruption dimmings that relate to strong currents are co-spatial with shear motion regions.

318 — Solar Physics Division Meeting (SPD), Helioseismology & Interior

318.01 — On the latitude dependence of Rossby waves in the Sun

Bastian Severin Niklas Proxauf[1]; Laurent Gizon[1]; Björn Löptien[1]; Jesper Schou[1]; Aaron C. Birch[1]; Richard S.

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We study the latitude and depth dependence of solar Rossby waves. We use horizontal flows from local helioseismology (ring-diagram analysis) at different depths in the solar interior. From these we compute maps of the radial vorticity. We confirm the existence of solar Rossby waves in the sectoral (m = l) power spectra at all depths down to 17 Mm below the surface. The depth dependence of the eigenfunctions is consistent with r^m, although this is a weak constraint due to the noise level. The latitudinal eigenfunctions are observed to be more narrow than $|\sin(\theta)|^m$, likely indicating that the modes sense the latitudinal differential rotation. Furthermore, we detect a non-zero imaginary component of the latitudinal eigenfunctions, possibly related to viscous dissipation. These new observations provide additional constraints on the physics of large-scale Rossby waves in the Sun.

318.02 — Probing the Variation with Depth of the Solar Meridional Circulation using Legendre Function Decomposition

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The solar meridional circulation is a crucial component of magnetic flux transport and dynamo models. Despite decades of helioseismic study, no consensus exists regarding the variation of its properties with depth. It has become apparent that the main challenges consist of 1) overcoming realization noise with multi-year long datasets, and 2) the identification and robust removal of systematic center-to-limb effects. Here we apply the helioseismic methodology of Legendre Function Decomposition (LFD) to 7.5 years of Dopplergrams obtained by the Helioseismic and Magnetic Imager (HMI) as the basis of inferring the depth variation of the meridional flow between 20 and 60 degrees latitude in both hemispheres. The LFD method, first developed by Braun and Fan in 1998, probes subsurface flows through the Doppler-effect induced distortion of power spectra. The procedure is optimized for the detection of meridional flows and uses Legendre functions (of the first and second kind) to characterize poleward and equatorward wave propagation in spherical coordinates. For this study we have developed control procedures which assess and remove center-to-limb artifacts, using measurements obtained by applying the procedure to pseudo poles at the east and west limbs. Forward modeling is carried out to evaluate the consistency of the corrected LFD frequency shifts with various assumed models of the depth variation of the meridional circulation.

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318.03 — Exploring the Coexistence of Two Distinct Dynamo States in the Sun through Global Simulations

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[1] *Astrophysical and Planetary Sciences, University of Colorado Boulder & JILA (Boulder, Colorado, United States)*

The origin of the Sun's magnetism remains one of the most pressing outstanding problems in solar physics. The number of sunspots (eruptions of magnetic flux through the photosphere) rises and falls over a regular 11-year cycle. Within each cycle, the sunspots emerge at mid-latitudes near solar maximum and then closer to the equator as the cycle progresses. Furthermore, the polarity sense of sunspot pairs is opposite in the Northern hemisphere compared to the Southern hemisphere, and this polarity sense flips from one 11-year cycle to the next. Recently, 3D, global, MHD dynamo simulations have made substantial contact with observations, yielding regular cycling, polarity reversals, and in a few cases, equatorward propagation of interior magnetic field. Here we present a new class of 3D, global simulations of a solar convection zone that remarkably achieve two distinct states of the dynamo coexisting simultaneously. One state consists of two opposite-polarity reservoirs of magnetism in each hemisphere that cycle, flip polarity, and exhibit equatorward propagation, in remarkable agreement with the observed solar cycle. Superimposed is another state, asymmetric about the equator, that consists of one reservoir of strong toroidal field in a single hemisphere that flips polarity and migrates poleward with the cycle, in agreement with many other dynamo simulations. We describe theoretically how our simulated dynamos might be achieved and whether such processes could be at work in the solar dynamo. We also investigate the possible observable signatures of two

distinct dynamo states if they were present in the solar interior.

318.04 — Deriving Three-Dimensional Sensitivity Kernels for Large-Scale Solar Interior Flows Using Wavefield Simulations

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[1] *Stanford Univ. (Stanford, California, United States)*
[2] *Bay Area Environmental Research Institute (Moffett Field, California, United States)*

At present, a common method for inferring the Sun's interior meridional-circulation profile is to invert helioseismically measured travel-time shifts using sensitivity kernels. The sensitivity kernels describe how much travel-time shifts are expected, caused by a flow at a certain interior location, at each surface measurement distance. Ray-approximation kernels, despite their shortcomings, have been used by many authors and provided tremendous insight into the solar interior. In the meantime, more realistic global-scale Born-approximation kernels have been developed by some authors. Here, we introduce a new approach for deriving three-dimensional flow kernels. We perform global-Sun wavefield simulations with small flow perturbations placed at pre-determined locations inside the simulated Sun, and measure the travel-time shifts they cause. A set of linear equations links the flow model, which we prescribe, and the travel-time shifts, which we measure from the simulated data, with the sensitivity kernels. By computing many such simulations, with perturbations at many different depths and locations relative to the wave source, this set of linear equations can be successfully solved numerically for the sensitivity kernels.

318.05 — Observational Constraints on the Solar Dynamo

Sushant Sushil Mahajan[1]
[1] *Physics & Astronomy, Georgia State University (College Park, Maryland, United States)*

Our analysis of helioseismic measurements of rotation rate in the solar interior show that latitudinal shear in differential rotation of the lower half of the convection zone is anti-correlated with the sunspot number. This is evidence for Parker's Ω-effect which proposes that the latitudinal shear is responsible for amplifying the sunspot producing toroidal field. Using the basic equations of magnetohydrodynamics (MHD) and integrating them over the closed volume of the convection zone, we have been able to show that the work done by Lorentz force is the source of magnetic energy inside the solar convection zone and the feedback of this Lorentz force on plasma explains the reduction of latitudinal shear in differential rotation when magnetic field is being inducted. During the two solar minima covered by the measurements, the differential rotation of the Sun was in the state of highest latitudinal shear which reduced during the rising phase of sunspot cycles and replenished during their declining phase. This suggests that the baseline differential rotation profile of the Sun is its profile near solar minimum, not the rotation profile obtained by calculating its mean rotation rate over a sunspot cycle.

We have also developed a significantly improved local correlation tracking algorithm for tracking magnetic features on the solar surface from line-of-sight magnetograms by removing several systematic effects like peak-locking, center-to-limb effect, etc. The new algorithm can detect shifts as small as 0.04 pixel whereas the original algorithm detected shifts larger than 0.2 pixels reliably. The measurements of large scale meridional flow and differential rotation on the solar surface obtained from line-of-sight magnetograms of MDI (1995-2011) and HMI (2010-2019) using the new algorithm suggest that the amplitude of meridional flow is anti-correlated with sunspot number. These large scale flow patterns serve as vital inputs for solar dynamo models and have implications for the prediction of the solar magnetic cycle.

318.06 — The Relationship Between Differential Rotation and Constant Effective Temperature in the Sun

Loren Matilsky[1]; Bradley W. Hindman[1]; Juri Toomre[1]
[1] *Astrophysical and Planetary Sciences, University of Colorado Boulder & JILA (Boulder, Colorado, United States)*

Helioseismology has shown that the rotation rate of the solar interior is constant along radial lines (conical rotation contours) and has a mostly uniform gradient from equator to pole, facts which are still not completely understood. Conical rotation contours and uniform rotation gradients have been reproduced in previous global, 3D, hydrodynamic simulations of the solar convective envelope by imposing a small temperature gradient at the base of the convective layer, consistent with thermal wind balance in the tachocline. Here we show that similar results can be obtained in global simulations by demanding that the conductive flux through the outer boundary of the convective layer (corresponding physically to the solar effective temperature) be constant with latitude. For the Sun, this is in line with observations

that show no significant dependence of the effective temperature with latitude. By contrast, if instead the entropy at the outer boundary is fixed (keeping all other simulation parameters constant), the outward conductive flux is allowed to vary with latitude and a markedly different rotation profile emerges, namely one that has cylindrical contours and strong rotation gradients confined mainly to low latitudes. We discuss in detail how the outer boundary condition on the entropy (fixed flux vs. fixed entropy) affects the dynamics responsible for the differential rotation achieved in our simulations.

319 — Karen Harvey Prize Lecture: Where Do Solar Eruptions Come From?, Anthony Yeates (Durham University)

319.01 — Where Do Solar Eruptions Come From?

Anthony R. Yeates[1]
[1] *Durham University (Durham, United Kingdom)*

An oft-quoted idea in solar physics is that coronal mass ejections are, fundamentally, the Sun's way of shedding the magnetic helicity that is continually generated by its interior flows. In this talk, I will show how models are helping to give us a handle on the build up of magnetic helicity in the corona (the Sun's lower atmosphere): how much is injected, where it collects, and how it is ultimately ejected. This endeavour is challenging because it requires us to move beyond static (but comfortable) potential-field extrapolations and develop time-evolving magnetic field models for the corona. At the quantitative level, even the definition of magnetic helicity is non-trivial. The relative magnetic helicity provides an excellent starting point, but to identify the spatial distribution of helicity within the corona we need a finer-grained measure. I will argue that "field line helicity" is a promising tool for this task, but it is only beginning to be developed

322 — iPoster Session: Stars & Friends II

322.01 — Measuring the Magnetic Field Strengths of K and M Stars

Maryam Hussaini[1]*; Gregory Mace*[1]
[1] *Astronomy, University of Texas at Austin (Round Rock, Texas, United States)*

We measured the magnetic field of a sample of K and M dwarfs by analyzing the Zeeman splitting effect on infrared spectra observed with the Immersion GRating INfrared Spectrometer (IGRINS). Magnetic field strengths were measured by fitting a double-Lorentzian to Sodium, Calcium, and Titanium lines. Knowledge of the magnetic field can be used to improve stellar interior models and theories on magnetic field generation. From the initial archive of >2500 spectra observed with IGRINS, 1075 were chosen for analysis based on the quality of the data and the exclusion of young and old stars that have not yet been calibrated. We determined precise magnetic field measurements for ~250 objects and upper limits for ~600 objects. The results of our research give us a new understanding of typical magnetic field strengths for low-mass stars and the dependence of these fields on changes to stellar interiors.

322.02 — A Universal Spin-Mass Relation for Brown Dwarfs and Planets

Dawn Peterson[1]*; Aleks Scholz*[2]*; Keavin Moore*[3]*; Ray Jayawardhana*[4]*; Suzanne Aigrain*[5]*; Beate Stelzer*[6]
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[3] *McGill University (Montreal, Quebec, Canada)*
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[5] *All Souls College (Oxford, United Kingdom)*
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While brown dwarfs show similarities with stars in their early life, their spin evolution is more similar to that of planets. We used lightcurves from the K2 mission to measure new rotation periods for 18 young brown dwarfs in the Taurus star-forming region. Our sample spans masses from 0.02 to 0.08 solar masses and has been characterized extensively in the past. To search for periods, we utilized three different methods (autocorrelation, periodogram, Gaussian Processes). Our results show the median period for brown dwarfs with disks is twice as long as for those without, a signature of rotational braking by the disk, albeit with small numbers. In addition, we confirmed the presence of a linear increase of the typical rotation period as a function of mass in the substellar regime. The rotational velocities, when calculated forward to the age of the solar system assuming angular momentum conservation, fit the known spin-mass relation for solar system planets and extrasolar planetary-mass objects. This spin mass trend holds over six orders of magnitude in mass, including objects from several different formation paths. Our result implies that brown dwarfs by and large retain their primordial angular momentum through the first few Myr of their evolution.

322.03 — Stellar Activity of Main Sequence Stars

Alex Larson[1]; Brendan P. Miller[1]; Steven H. Saar[4]; Elena Gallo[2]; Jason Wright[3]; Cedric Hagen[5]

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Many main sequence stars have chromospheric activity levels that vary with time. These can be characterized based on their Ca II H and K line core emission. Using data obtained from the California Planet Search we fit a sinusoidal function to a sample of 244 stars to test for significant cyclic variability. We wrote a python program to analyze observations taken over timescales of up to 17 years to determine optimal sinusoidal parameters, with uncertainties estimated through a bootstrapping technique. We also identify some inactive stars with virtually no R'HK variability. We find that within our sample the less active cyclic stars tend to have longer periods. Ongoing work examines the potential impact of cyclic and flaring stellar activity on known exoplanets, including those orbiting within the habitable zone.

322.04 — Hot subdwarf B stars in the age of Kepler and Gaia

David Brown[1]

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Hot subdwarf B stars are thought to be core-He burning stars having masses of approximately $0.5M_{\odot}$, surrounded by thin hydrogen envelopes with masses of $M_{env} \leq 0.02M_{\odot}$. They are the field equivalents of extreme horizontal branch (EHB) stars in globular clusters. Although their formation mechanisms remain unknown, it is thought that they form from progenitors which have experienced a phase of rapid mass loss, typically when they are in the red giant branch stage of evolution, shortly before ignition of their helium cores. Single-star progenitor scenarios of their formation posit that the mass loss in EHB progenitors is due either to a high stellar wind and/or a weak binding energy for their envelopes. Then again, evidence of multiple populations found in globular clusters suggests that such hot EHB stars might result from He-enhancement (in such clusters) from material enriched by the ejecta of earlier-generation AGB stars. Alternatively, the extreme mass loss, which might take place in hot subdwarf star progenitors, could be explained through binary interactions. Here, the extreme mass loss would be the result of the sdB progenitor experiencing a period of Roche Lobe Overflow (RLOF). Han et al. (2002, 2003) explored such binary formation channels for hot subdwarf stars for Z=0.02, presenting a compelling theoretical analysis of three possible binary formation scenarios for sdB stars from either a series of common envelope (CE) phases of mass loss, or stable mass loss due to RLOF, or due to the merger of two He WD stars. Their results correlated well with the finding from Maxted et al. (2001) that most field sdB stars are found in binary systems. In turn, Brown has studied the same binary formation channels, this time for multiple chemical environments having different metallicities (Z=0.0001, 0.001, 0.02, 0.03, 0.04, 0.05). The era the Kepler and Gaia surveys has presented ample data to be able to begin to test these binary formation channels, something explored in this poster.

322.05 — Photometric Observations and Modeling of Eclipsing Binaries NSVS 4312042 and NSVS 2910034

R. Wes Tobin[1]; Robert C. Berrington[2]

[1] Natural Sciences, Indiana University East (Richmond, Indiana, United States)

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We present BVR photometric observations and preliminary analyses of two eclipsing binary systems: NSVS 4312042 and NSVS 2910034. Systems are modeled using the PHysics Of Eclipsing BinariEs program, which utilizes the Wilson-Devinney code to determine best-fit stellar models. Modeling provides some constraint on the physical parameters of each system, even without radial velocity measurements. Preliminary results of NSVS 4312042 indicate that it appears as a typical contact binary that matches expectations as a W UMa system. Preliminary results of NSVS 2910034 indicate that the light curve exhibits a discernible O'Connell effect. Modeling of NSVS 2910034 appears to suggest that it may be a semi-detached binary system, which would be inconsistent with its initial classification as a W UMa system. Implications and likelihoods are discussed.

322.06 — A Search for Helium-Core White Dwarfs in the Globular Cluster 47 Tuc

Sarah Deveny[1]; Adrienne Cool[1]; Craig O. Heinke[2]; Liliana Rivera Sandoval[6]; Maureen van den Berg[3]; Jay Anderson[4]; Phyllis Lugger[5]; Haldan Cohn[5]

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We report preliminary results of a search for helium-core white dwarfs (He WDs) in the globular cluster 47 Tuc. These low-mass white dwarfs are understood to form in binary systems in which a star's evolution is interrupted as it climbs the red giant branch. As such, He WDs can provide a window into the binary star populations in globular clusters. Using WFC3/UVIS data from the Hubble Space Telescope in two filters, F300X and F390W, we construct a color-magnitude diagram and begin by selecting a subset of the best-measured stars in the cluster. From this cleaned diagram we isolate a population of ∼50 candidate low-mass white dwarfs. Comparing the radial distribution of these stars to the radial distributions of other populations of known mass in 47 Tuc, we show that the He WDs are more centrally concentrated than can be explained if they are single stars. This makes 47 Tuc the third cluster in which a significant population of probable binary stars containing He WDs has been identified.

322.07 — Digging Deeper into the Properties of a Cooling Neutron Star's Crust

Michael Ross[1]; William Newton[1]; Lauren Balliet[1]

[1] *Physics and Astronomy, Texas A&M University - Commerce (Greenville, Texas, United States)*

Low Mass X-ray Binaries are star systems in which a neutron star or a small black hole is paired with a companion star with mass comparable to that of the sun. During accretion, the companion star donates matter to the compact object in the system and increases its temperature. When accretion ends, a stage called quiescence, the compact object begins to cool as it moves back toward thermal equilibrium. Properties of various neutron stars' crusts can be modeled based on how long the stars take to return to thermal equilibrium. Previous research demonstrated an inverse-square relationship between the impurity of neutron star crust and the radius of the star. ∼100 combinations of possible radii, crust pressures, star masses, and maximum possible mass before black hole collapse were generated by an equation of state (EOS) and were used to arrive at the previously mentioned conclusion. Current research focuses on demonstrating a more in-depth relationship between the neutron star radius and crustal impurity by using ∼4000 combinations of generated parameters created by multiple EOSs.

322.08 — Machine Learning for Turbulence in Supernovae

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Turbulence plays a significant role in many different phenomena, including Core-Collapse Supernovae (CCSN). Unfortunately, current state-of-the-art simulations have to resort to using subgrid models for turbulence treatment, as direct numerical simulations (DNS) are too expensive to run. However, said subgrid models, such as large eddy simulation (LES), lack accuracy when compared to DNS results. Recently, there has been a new trend of utilizing Machine Learning (ML) technique, with impressive prediction capability for the turbulence closure. We have applied Kernel Ridge Regression to investigate the accuracy and applicability of these algorithms in regards to magnetohydrodynamic (MHD) turbulence subgrid modeling. Our future goal is to ready and apply our ML methodology within the multi-D MHD CCSN framework to investigate the effects of accurately-modeled turbulence on the explosion rate of these events.

400 — Plenary Session: From Native Skywatchers to ASTR 101…New Designs for Interdisciplinary, Multidisciplinary, and Transdisciplinary Engaged Learning Now, Annette Lee (St. Cloud University) and Bill Iseminger (Cahokia Mounds Historic Site)

400.01 — From Native Skywatchers to ASTR 101 … New Designs for Interdisciplinary, Multidisciplinary, and Transdisciplinary Engaged Learning Now

Annette S. Lee[1,2]
[1] *Physics and Astronomy, St. Cloud State University (St. Cloud, Minnesota, United States)*
[2] *University of Southern Queensland (Toowoomba, Queensland, Australia)*

"*Learn to see from one eye with the best in Indigenous knowledges, and from the other eye with the best in Western knowledge…and learn to use both these eyes together for the benefit of all… the gift of multiple perspectives.*" — Elder Albert Marshall from the Mi'kmaq Nation

Designed by 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 traditionally 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 people to have a rekindling or deepening sense of awe and personal relationship to the cosmos. Presented here will be strategies and best practices for effective and inclusive widening participation in science through astronomy. Of particular emphasis will be the connection between indigenous worldviews, narrative, and the visual language, and how this informs the teaching and strategies in large lecture introductory astronomy college courses.

Currently Annette is an Associate Professor of Astronomy & Physics at St. Cloud State University (SCSU), Director of the SCSU Planetarium, and Honorary/Adjunct Associate Professor at the University of Southern Queensland (USQ) in the Centre for Astrophysics, Distinguished Lecturer-Archaeological Institute of America (IAI)-Webster Lectureship, and an American Astronomical Society (AAS) Shapley Lecturer. Annette is mixed-race Lakota and her communities are Ojibwe and D/Lakota.

400.02 — Cahokia Mounds: America's First City

William Iseminger[1]
[1] *Cahokia Mounds State Historic Site (Collinsville, Illinois, United States)*

Cahokia Mounds was the largest prehistoric Indian community in America north of Mexico and at its height covered six square miles, included 120 earthen mounds, and a population estimated to have been 10-20,000. Built by the Mississippian culture, it flourished from about AD 1000-1350. The presentation will include discussions of the culture and the major site features, including the Woodhenge sun calendars, the defensive Palisade wall, the ritual burials of Mound 72, the Grand Plaza, and 100-foot-high Monks Mound, the largest prehistoric earthwork in the Americas. It was also the center of a major prehistoric urban complex known as Greater Cahokia that included the mound complexes in St. Louis and East St. Louis, smaller mound sites, and numerous moundless hamlets and farmsteads.

401 — iPoster Plus XI: (SPD), Magnetic Fields

401.01 — Long-Term Prediction of Solar Activity Using Magnetogram Data and Ensemble Kalman Filter

Irina Kitiashvili[1]*; Alexander G. Kosovichev*[2]
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Solar activity predictions using the data assimilation approach have demonstrated great potential to build reliable long-term forecasts of solar activity. In particular, it has been shown that the Ensemble Kalman Filter (EnKF) method applied to a non-linear dynamo model is capable of predicting solar activity up to one sunspot cycle ahead in time, as well as estimating the properties of the next cycle a few years before it begins. These developments assume an empirical relationship between the mean toroidal magnetic field flux and the sunspot number. Estimated from the sunspot number series, variations of the toroidal field have been used to assimilate the data into the Parker-Kleeorin-Ruzmakin (PKR) dynamo model by applying the EnKF method. The dynamo model describes the evolution of the toroidal and poloidal components of the magnetic field and the magnetic helicity. Full-disk magnetograms provide more accurate and complete input data by constraining both the toroidal and poloidal global field components, but these data are available only for the last four solar cycles. In this presentation, using the available magnetogram data, we discuss development of the methodology and forecast quality criteria (including forecast uncertainties and sources of errors). We demonstrate the influence of limited time series observations on the accuracy of solar activity predictions. We present EnKF predictions of the upcoming Solar Cycle 25 based on both the sunspot number series and observed magnetic fields and discuss the uncertainties and potential of the data assimilation approach. The research is funded by the NSF SHINE program AGS-1622341.

401.02 — (withdrawn)

This abstract was withdrawn.

401.03 — Polar magnetic field in solar cycle 24

Nariaki Nitta[1]

[1] *Lockheed Martin, ATC (Palo Alto, California, United States)*

Coronal holes often sit in Sun's polar regions, and they are believed to be responsible for the fast solar wind. The magnetic field therein is open to the heliosphere. It is possible that such field may emanate from small patches with enhanced field strength, which were first revealed in data from the Spectropolarimeter (SP) of the Hinode Solar Optical Telescope. It has recently been shown that very similar patches can be found in vector magnetograms from the Helioseismic and Magnetic Imager (HMI) on the Solar Dynamics Observatory (SDO), even though SP has better spatial resolution and vector magnetography. An advantage of SDO/HMI is constant availability of full-disk vector data. This allows us to make movies of radial field in polar regions with varying cadences, which can be used to study the dynamical evolution of the patchy magnetic field regions in high latitudes, such as poleward of 60 degrees, generally difficult to observe from an ecliptic vantage point. We discuss the general distribution of magnetic field in polar regions over solar cycle 24 using such movies. The patches of enhanced radial field are compared with certain types of solar activity such as coronal jets. We emphasize the limitation of the existing data for studying polar field.

402 — Solar Physics Division Meeting (SPD), Magnetic Fields

402.01 — Evolution of Flows around Emerging Active Regions

Nils Gottschling[1]*; Hannah Schunker*[1]*; Aaron C. Birch*[1]*; Laurent Gizon*[1]

[1] *Solar and Stellar Interiors, Max Planck Institute for Solar System Research (Goettingen, Lower Saxony, Germany)*

Inflows associated with established active regions have been measured with velocities of about 30 m/s and extending up to 10° from the active regions, but have so far been included in surface flux transport models only in a simple form. How these flows develop as active regions emerge has not yet been studied. We measure the flows surrounding 182 emerging active regions observed by the SDO/HMI instrument using local correlation tracking of the granulation as they evolve from seven days before to seven days after emergence. We find flows converging towards the trailing polarity at the time when magnetic flux first emerges. Three days later, extended inflows form towards the center of the active region predominantly in the north-south direction, together with outflows at the leading polarity, due to moat flows around sunspots. The flows have velocities of 20 to 30 m/s and increase in extent from about 2° to about 7°. At later times, the flows resemble those from previous studies of established active regions. These results will help constrain models of the surface evolution of magnetic fields.

402.02 — Measuring and Characterizing the Importance of Magnetic Flux Cancellation in Solar Active Regions during their Emergence Phase

Georgios Chintzoglou[1]*; Mark Cheung*[1]

[1] *Lockheed Martin Solar and Astrophysics Lab (Palo Alto, California, United States)*

Active Regions (ARs) in their emergence phase are known to be more flare productive and eruptive than ARs in their decay phase. For decaying ARs, the flaring and eruptive activity is thought to be a consequence of the formation of magnetic flux ropes through photospheric magnetic flux cancellation, often occurring at the internal polarity inversion line

(PIL) of the AR. Typically, during the AR decay phase, flux cancellation manifests itself by a clear decay of the total unsigned magnetic flux, sometimes preceding and even accompanying the flaring and eruptive activity. In emerging ARs, however, no cancellation can be seen in the total unsigned magnetic flux owing to sustained flux emergence. In this work we focus on complex emerging ARs composed of multiple bipoles. Due to the compact clustering of the different bipoles within such complex multipolar ARs, collision and shearing between opposite non-conjugated polarities drives rapid photospheric cancellation. This mechanism is called collisional shearing. In Chintzoglou et al (2019), it was demonstrated that collisional shearing occurred in two emerging flare and CME productive ARs (NOAA AR11158 and AR12017) and a significant amount of cancelled flux was measured by applying the conjugate flux deficit method (Chintzoglou et al 2019). Here, we employ a new methodology based on a novel electric field inversion method and we calculate the time evolution of magnetic flux through Faraday's law at the internal PIL of emerging ARs. We compare this methodology with the conjugate flux deficit method on magnetogram series of synthetic and observed emerging ARs and discuss our results in relation to flare and eruptive activity.

402.03 — On Evolution of Magnetic Helicity in Solar Bipole Active Regions

Yang Liu[1]
[1] *Stanford University (Palo Alto, California, United States)*

Using SDO/HMI vector magnetic field data, we study magnetic helicity evolution in bipole active regions. We compute helicity flux through the photosphere for a sample of emerging active regions with bipole magnetic configuration. We then explore relationship between the accumulated helicity in the active regions and the total magnetic flux. A relationship between helicity and magentic flux is found in a subgroup of the active regions, suggesting a unique property of magnetic twist in these active regions. We discuss implication of this relationship here.

402.04 — Contribution of Doppler Velocity to Active Region Energy and Helicity Flux Estimate

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[3] *Space Science Laboratory, University of California Berkeley (Berkeley, California, United States)*

The advent of routine photospheric vector magnetograms now allows for realistic estimate of active region (AR) energy and helicity flux. Such estimate requires information of the surface velocity field. Here, we calculate the energy and helicity flux for AR 12673 where significant Doppler flows (V_l) were observed along the magnetic polarity inversion line. Results based on the DAVE4VM velocity estimate (without V_l information) and the CGEM electric field inversion (with V_l) algorithms differ significantly, mainly due to the additional constraint from V_l. We argue that Dopper velocity needs to be included for realistic flux estimate. We describe an updated DAVE4VMWDV velocity estimate algorithm that incorporates such contribution.

402.05 — Multi-wavelength Multi-height Study of Super Strong Surface and Coronal Magnetic Fields in Active Region 12673

Haimin Wang[2]*; Bin Chen*[1]*; Ju Jing*[2]*; Sijie Yu*[1]*; Chang Liu*[2]*; Vasyl B. Yurchyshyn*[2]*; Kwangsu Ahn*[2]*; Takenori Okamoto*[3]*; Shin Toriumi*[3]*; Wenda Cao*[2]*; Dale E. Gary*[1]
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Using the joint observations of Goode Solar telescope (GST), Expanded Owens Valley Solar Array (EOVSA), Solar Dynamics Observatory (SDO) and Hinode, we study the Solar Active Region (AR) 12673 in September 2017, which is the most flare productive AR in the solar cycle 24. GST observations show the strong photospheric magnetic fields (nearly 6000 G) in polarity inversion line (PIL) and apparent photospheric twist. Consistent upward flows are also observed in Dopplergrams of Hinode, HMI and GST at the center part of that section of PIL, while the down flows are observed in two ends, indicating that the structure was rising from subsurface. Combining Non-Linear Force Free Extrapolation and EOVSA microwave imaging spectroscopy, we also look into the coronal structure of magnetic fields in this unusual AR, including the evolution before and after the X9.3 flare on September 6, 2017. Coronal fields between 1000 and 2000 gauss are found above the flaring PIL at the height range between 8 and 4Mm, outlining the structure of a fluxrope or sheared arcade.

403 — Gravitational Waves & Instrumentation: Space Missions

403.01 — Searches in Advanced LIGO and Advanced Virgo data for continuous gravitational waves

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The LIGO Scientific Collaboration and Virgo Collaboration have carried out joint searches in Advanced LIGO and Advanced Virgo data (observing runs O1 and O2) for periodic continuous gravitational waves. These analyses range from targeted searches for gravitational-wave signals from known pulsars, for which ephemerides from radio, X-ray or gamma-ray observations are used in precise templates, to all-sky searches for unknown neutron stars, including stars in binary systems. Between these extremes lie directed searches for known stars of unknown spin frequency or for new unknown sources at specific locations, such as near the galactic center. Recent and ongoing searches of each type will be summarized, along with prospects for future searches using more sensitive data from the ongoing O3 observing run and from future runs.

403.02 — Linking neutron star observations and nuclear observables consistently

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Using a new suite of equations of state parameterized entirely by neutron star and nuclear observables, we explore consistently the correlations between neutron star crust and core properties, neutron skins and other nuclear observables. The equations of state are based on an extended Skyrme energy density functional up to one and a half times saturation density, and on polytropes at higher densities. Each equation of state is characterized by 5 parameters: the first three symmetry energy parameters in its density expansion about saturation density, the moment of inertia of 1.337 solar mass neutron star, and the neutron star maximum mass. The three symmetry energy degrees of freedom are varied to systematically cover the whole parameter space allowed by microscopic calculations of pure neutron matter, and the remaining parameters uniformly span the range of values consistent with causality and the existence of a 2.0 solar mass neutron star. Each equation of state comes with its own consistently calculated crust model and a set of neutron skin and nuclear giant resonance predictions, allowing consistent propagation of constraints between the nuclear and astrophysical domains.

403.03 — Measuring the tidal deformability of GW170817's component stars using consistent chiral-EFT equations of state

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GW170817 provided the unprecedented opportunity to constrain the equation of state (EOS) of matter at super-nuclear densities using gravitational waves. This has been accomplished via Bayesian inference of the mass and tidal deformation of the component objects. Previous studies assumed that the EOS of the components of GW170817 were either exactly the same, or completely uncorrelated. Neither of these assumptions is expected to be entirely correct if the component objects are neutron stars. Chiral effective field theory (EFT) provides a framework for quantifying the uncertainty in a neutron star's EOS due to two- and three-nucleon interactions. In this study, we consider generic equations of state from chiral EFT when using Bayesian inference to measure the tidal deformability of the components of GW170817. This can allow us to constrain the allowed EFTs from gravitational-wave observations.

403.04 — NASA Astrophysics CubeSats and SmallSats

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The NASA Astrophysics Division is currently funding five science CubeSats which are in various stages of operation or construction, and also nine studies of astrophysics science SmallSats. I review the status of these, the funding opportunities, and possible path(s) forward.

403.05 — Placeholder: Abstract Moved 402.05

403.06 — Updated Standard Evaluation of exoplanet Yield for the LUVOIR and HabEx Concept Studies

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The HabEx and LUVOIR concepts aim to directly image and spectrally characterize potentially habitable exoplanets. Using EXOSIMS, realistic mission observing constraints, and dynamically responsive scheduling, we simulate the exoplanet detection and characterizations over Monte Carlo realizations of synthetic planets around nearby stars. We use identical astrophysical inputs and the observing scenarios of each concept to evaluate a common comparison of the detection and spectral characterization yields of HabEx and LUVOIR. HabEx is evaluated for the 4m hybrid starshade and coronagraph architecture, the 4m coronagraph only architecture, and the 3.2 m starshade only architecture. LUVOIR is evaluated for the 15 m on-axis and 9 m off-axis architectures. The scenarios are scheduled to respond dynamically to the number of detections/no-detections of a target and success of characterization as well as the optimal slews for the starshade. Yield analysis shows that both concepts can directly image and spectrally characterize earth-like planets in the Habitable zone and that each concept has complementary strengths.

403.07 — Enhanced and Enabled Astrophysical Observations with System-Level Autonomy

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A system-level autonomy framework enables a complex system to accomplish stated goals while observing and reacting to changes within the system and its operating environment without traditional human intervention. As witnessed in automotive and aviation sectors, system-level autonomy has realized capabilities only previously imagined. The impact of these capabilities on our ability to observe the universe will be just as revolutionary.

The missions and systems currently under study for the Astro2020 Decadal are larger in size and more complex than past missions, with larger platforms, actuated optics, multiple flight systems, and complicated focal planes. With new complexity comes new threats to nominal operations and a mission's ability to return the science without disruption. Increasing the degree of autonomy is enhancing to all space- and ground-based observatories by defining resilient operations where science can continue despite anomalies, and increasing observing capability while reducing costs.

An autonomous observing system can respond to failures by exploring different strategies to retry or attempt corrective measures to resume nominal operation. An autonomous framework defines a distinction between system-level and function-level control that is generic to the mission system; thus, patterns of behavior on one mission can be utilized on other missions to reduce development, testing, and operational costs.

System-level autonomy enables new architectures. Here, the planning/schedule approach for a single spacecraft can be generalized to support multiple spacecraft using multi-agent autonomy. Complex, interferometric missions – like LISA – are enabled. Similarly transient event missions, like those observing multi-messenger signals, can be designed at lower cost as transient response no longer needs to be custom designed for that given mission, but is designed as an extension to existing autonomous planning/execution capabilities. System-level autonomy can be deployed on ground-based observatories to respond dynamically to sky conditions to execute alternate observations when scheduled observations are not possible.

403.08 — (withdrawn)

This abstract was withdrawn.

404 — Plenary Lecture: The Apollo Lunar Exploration Program: Scientific Impact and the Road Ahead, James Head (Brown University)

404.01 — The Apollo Lunar Exploration Program: Scientific Impact and the Road Ahead

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Half a century ago, the Apollo lunar exploration missions began the transformation of the Moon, terrestrial planets and outer planet satellites, from objects of astronomical study to objects of geologic exploration and characterization. The Apollo missions re-

solved fundamental questions about the Moon (Origin of the Moon and its craters, the age and origin of the maria, the formation of basins; Did the Moon form hot or cold?). It also provided a fundamental framework and paradigm for understanding the history and evolution of the terrestrial planets, including Earth. What have we learned about planetary formation and evolution in the ensuing five decades from this Moon-based comparative planetology? Ejecta from a large Mars-sized projectile impacting into early Earth appears to have formed the Moon. Impact cratering plays a fundamental role in initial impact heating and melting to create a molten magma ocean whose thermal and chemical evolution dictates much of subsequent history. Planetary internal heating, melting and extrusion of molten rock (lava) to the surface supplies additional volatiles to the primordial atmospheres and resurfaces significant areas. Earth loses heat through plate tectonics, but smaller bodies lose heat primarily by conduction and rapidly become "one-plate planets". Planets lose atmospheres as a function of time and Mars is a laboratory for this change, perhaps evolving from warm and wet to today's sub-freezing desert. The current position of planets relative to their stars is not necessarily where they started out. Abundant planetary environments have the ingredients for life, but life has thus far only been detected on Earth. As usual, astronomers are leading the way to the future, with the discovery of many dozens of exoplanetary systems and thousands of exoplanets. Today astronomers and planetary scientists are teaming up to tackle fundamental questions in comparative planetary systems: How can we use our knowledge about our Solar System and the characteristics and histories of its planets and satellites to interpret the nature of exoplanets? Where does the Solar System fit in the menagerie of exoplanetary systems? Is our Solar System typical or anomalous?