Abstracts of the 17th HEAD Meeting (Monterey, CA)

American Astronomical Society

March, 2019

100 — Stellar Compact I

100.01 — Ultraluminous X-ray Sources in Extragalactic Globular Clusters

Kristen Dage[1]; Stephen Zepf[1]; Mark Peacock[1]; Arash Bahramian[1,2]; Arunav Kundu[3]; Thomas Maccarone[4]

[1] *Michigan State University (East Lansing, Michigan, United States)*
[2] *ICRAR (Perth, Western Australia, Australia)*
[3] *Eureka Scientific (Oakland, California, United States)*
[4] *Texas Tech University (Lubbock, Texas, United States)*

The question whether globular clusters host black holes has been of longstanding interest. This interest has grown dramatically with the LIGO detection of merging black holes, as black hole mergers formed in globular clusters is one of the leading explanations for these LIGO sources. Determining whether black holes are common in globular clusters (GCs) has been an observational challenge. One of the most successful ways to identify candidate black holes in globular clusters is to identify globular cluster X-ray sources with very high luminosities that are much greater than the Eddington limit for neutron stars. A number of ultraluminous X-ray sources (ULXs) have been found within extragalactic globular clusters, and are candidate accreting black holes. We study spectral properties of GC ULXs over a large span of Chandra observations. We find that the globular cluster ULXs seem to follow one of two distinct trends: one group show a strong correlation between the accretion disk temperature and X-ray luminosity, while another group show no change in disk temperature with significant variations in X-ray luminosity. We discuss how these observational results impact our understanding of the nature of these sources and compare them to ULXs in star forming regions (very different environments than globular clusters) where a number have been shown to be NSs.

100.02 — Understanding the orbital period and accretion torque in the ultra-luminous X-ray pulsar NGC 7793 P13

Felix Fuerst[1]; Dom Walton[2]; Marianne Heida[3]; Fiona Harrison[3]; Didier Barret[4]; Murray Brightman[3]; Andrew Fabian[2]; Matthew Middleton[5]; Ciro Pinto[2]; Virkam Rana[6]; Frank Tramper[1]; Natalie Webb[4]; Peter Kretschmar[1]

[1] *ESA/ESAC (Villanueva de la Canada, Madrid, Spain)*
[2] *IoA Cambridge (Cambridge, United Kingdom)*
[3] *Caltech (Pasadena, California, United States)*
[4] *CNRS (Toulouse, France)*
[5] *University of Southampton (Southampton, United Kingdom)*
[6] *Raman Research Institute (Bangalore, India)*

Ultra-luminous X-ray pulsars (ULPs) are a new class of accreting neutron stars, emitting X-rays orders of magnitude above their Eddington limit. Currenlty only five ULPs are confirmed. Among them, NGC 7793 P13 stands out among as being relatively easily observable and as the only one with a clearly identified optical companion, a B9I supergiant. This allows us to study the binary properties in detail and shed light on the accretion mechanism in this rare source type. The pulsations of the neutron star have a period around 415ms and have been detected in all X-ray observations so far, allowing us to study the long-term spin evolution. I will present results from our 2017-2018 XMM-Newton and NuSTAR campaign on this source. Through X-ray timing, we follow the pulse period evolution and we can unambiguously measure the orbital period to be ~64d. Together with the properties of the mass donor, we describe, for the first time in a ULP, the ephemeris of the system fully. The orbital period is consistent with the optical photometric period, but significantly shorter than the periodicity of the X-ray flux ($P_X \sim 66.5$d). I will discuss possible explanations for this difference, like a very long super-orbital or a super- hump period. Adding new data from the end of 2018 we see that the spin-up of the source has accelerated, likely due to an increased accretion torque. I will put these findings into context with the other known ULPs and galactic sources.

100.03 — A Comprehensive Chandra Study of the Disk Winds in the Black Hole Candidate 4U 1630-472

Nicolas Antonio Trueba[1]; Jon Miller[1]; Jelle Kaastra[2]; Abderahmen Zoghbi[1]

[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

[2] *SRON Netherlands Institute for Space Research (Utrecht, Netherlands)*

The mechanisms that drive disk winds are a window into the physical processes that underlie the accretion disk itself, as well as feedback within the broader accretion flow. Transient stellar-mass black holes are an ideal setting in which to explore these mechanisms since their outbursts span a broad range in mass accretion rate. We present a detailed spectral analysis of the disk winds found in six Chandra/HETG observations of black hole candidate 4U 1630–472, spanning a wide range of luminosities over two distinct spectral states. Two independent constraints on launching radii were obtained via the ionization parameter formalism and the dynamical broadening of wind re- emission; thereby enabling the characterization of the wind geometry without the need of assuming a fiducial gas density. All wind components display evidence of magnetic driving with launching radii too small for winds arising purely via thermal driving. The innermost wind components (r $\sim 10^{2-3}$ GM/c^2) are the densest and fastest, while the outer components (r $\sim 10^5$ GM/c^2) have low densities and outflow velocities typically associated with thermal winds. This picture is consistent with thermal driving becoming efficient at larger radii, and even suggests the possible detection of a thermal/magnetic 'hybrid' wind. Finally, we find wind mass outflow rates that either match or exceed the mass accretion rate, supporting the view that disk winds are an important component of the overall accretion flow.

100.04 — The New Black Hole Binary Candidate Swift J1658.2-4242 Observed by NuSTAR, Swift and XMM-Newton

Yanjun Xu[1]; Fiona Harrison[1]; John Tomsick[2]; Jamie Kennea[3]; Dom Walton[4]; Jon Miller[5]; Didier Barret[6]; Andrew Fabian[4]; Karl Forster[1]; Felix Fuerst[7]; Poshak Gandhi[8]; Javier A. García[1]

[1] *Caltech (Pasadena, California, United States)*

[2] *SSL/UCB (Berkeley, California, United States)*

[3] *Pennsylvania State University (University Park, Pennsylvania, United States)*

[4] *University of Cambridge (Cambridge, United Kingdom)*

[5] *University of Michigan (Ann Arbor, Michigan, United States)*

[6] *Universite de Toulouse (Toulouse, France)*

[7] *ESA/ESAC (Madrid, Spain)*

[8] *University of Southampton (Southampton, United Kingdom)*

Swift J1658.2-4242 is a new Galaltic black hole binary candidate viewed at high inclination angle discovered during its outburst in early 2018. We obtained broadband X-ray obervations by NuSTAR, Swift and XMM-Newton in the hard and intermediate state, on the rising phase of the outburst. We observe strong disk reflection features with NuSTAR in the hard state, challenaging the truncated disk hypothesis for the low/hard state of black hole binaries. We also perform detailed spectral modeling yielding a high black hole spin. An aborption feature is found in the Fe K band in the NuSTAR spectra, impling the unusual presence of a disk wind in the hard state. In the intermediate state, a peculiar event is observed where the X-ray flux significantly decreased in 40s with a turn-on of a low-frequency QPO, while being accompanied by only minor changes in the shape of the broadband X-ray spectrum. In addition, strong relativistc reflection features previously detected in the hard state are absent. We present the unusual phenomena observed in Swift J1658.2-4242 and results from our spectral and timing analyses, and discuss their implications for the dynamical properties of the inner accretion flow around black hole.

100.05 — Accretion States and BH Spin in MAXI J1535-571 with NICER and NuSTAR

Joey Neilsen[1]; James F. Steiner[2]; Ron Remillard[2]; Phil Uttley[3]; Jeroen Homan[4]; Liam Jones[1]; Sara Motta[5]; Mickaël Coriat[6]; Rob Fender[5]; Stephane Corbel[8]; Gabriele Ponti[7]; Zaven Arzoumanian[9]; Keith Gendreau[9]; Renee Ludlam[10]

[1] *Department of Physics, Villanova University (Villanova, Pennsylvania, United States)*

[2] *University of Michigan (Ann Arbor, Michigan, United States)*

[3] *MIT (Cambridge, Massachusetts, United States)*

[4] *University of Amsterdam (Amsterdam, Netherlands)*

[5] *Eureka Scientific (Oakland, California, United States)*

[6] *Oxford (Oxford, United Kingdom)*

[7] *IRAP (Toulouse, France)*

[8] *MPE (Garching, Germany)*

[9] *CEA Saclay (Saclay, France)*

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

After two decades of monitoring stellar mass black holes in outburst, there are still lingering questions

about the geometry of the accretion disk and its evolution across state transitions. Does the disk extend all the way to the ISCO, or is it truncated at some distance from the black hole? How does this depend on accretion rate, luminosity, and X-ray spectral shape, and how is it connected to timing properties? The recent outburst of MAXI J1535-571, monitored extensively with NuSTAR and NICER, provides a prime opportunity to address these questions. I will present detailed analysis of the spectral evolution of the source over roughly three months, from its rising hard states through its >5 Crab peak, all the way to its soft, disk-dominated state. Applying relativistic reflection models and holding its spin constant across the outburst, I track the evolution of the inner radius of the disk from state to state. With hundreds of millions of counts in dozens of observations, these data offer an incredibly detailed view of the spectral geometry of MAXI J1535-571 for comparison to precision timing results.

100.06 — Spectral Evolution in the Ultra-compact X-ray binary 4U 1543-624 during the 2017 Outburst

Renee Ludlam[1]; Jon Miller[1]; Laura Shishkovsky[2]; Javier A. García[3]; James Miller-Jones[5]; Andrew Fabian[6]; Keith Gendreau[7]; Zaven Arzoumanian[7]; Lorenzo Natalucci[4]; Mariateresa Fiocchi[4]

[1] *Department of Astronomy and Astrophysics, University of Michigan (Ann Arbor, Michigan, United States)*

[2] *Michigan State University (East Lansing, Michigan, United States)*

[3] *California Institute of Technology (Pasadena, California, United States)*

[4] *INAF-IAPS (Rome, Italy)*

[5] *Curtin University (Perth, Western Australia, Australia)*

[6] *Institute of Astronomy (Cambridge, United Kingdom)*

[7] *NASA GSFC (Goddard, Maryland, United States)*

Ultra-compact X-ray binaries consist of a compact object that is typically accreting from a degenerate companion star in a binary orbit of less than 80 minutes. These systems are strong gravitational wave sources for future missions, such as LISA, that are sensitive in the sub-MHz regime. As a result, it is important to understand the properties of these systems as we enter the era of multi-messenger astronomy. We report on NICER, Swift, Integral, and ATCA observations of 4U 1543-624 during an enhanced accretion episode in August 2017. There is clear spectral evolution in the thermal component as the intensity increases. Additionally, we observe a prominent oxygen feature at ~0.65 keV that responds to the changes in the continuum during outburst. Our ATCA observations place an upper limit on the radio flux of the source. Combined with the X-ray flux at the time of the radio observations, we can place the source on the radio–X-ray "fundamental" plane of accretion activity. The position on the Lr-Lx plane falls significantly below what is expected for black holes. This further supports the common assumption that the compact object in 4U 1543-624 is a neutron star, although no Type-I X-ray bursts have ever been observed.

101 — AGN I

101.01 — The ongoing transformation of Seyfert galaxy 1ES 1927+654

Erin Kara[1]; Claudio Ricci[2]; Benny Trakhtenbrot[3]; Iair Arcavi[3]; Michael Loewenstein[1]; Andrew Fabian[4]; Keith Gendreau[5]; Ronald Remillard[6]; Zaven Arzoumanian[5]; Chelsea Macleod[7]; Edward Cackett[8]; Diego Altamirano[9]; Dheeraj Pasham[6]; James F. Steiner[6]; Kent Wood[10]

[1] *Department of Astronomy, University of Maryland / NASA GSFC (College Park, Maryland, United States)*

[2] *Praxis, Inc. (Alexandria, Virginia, United States)*

[3] *Universidad Diego Portales (Santiago, Chile)*

[4] *Tel Aviv University (Tel Aviv, Israel)*

[5] *University of Cambridge (Cambridge, United Kingdom)*

[6] *NASA GSFC (Greenbelt, Maryland, United States)*

[7] *MIT Kavli Institute (Cambridge, Massachusetts, United States)*

[8] *Harvard CfA (Cambridge, Massachusetts, United States)*

[9] *Wayne State University (Detroit, Michigan, United States)*

[10] *University of Southampton (Southampton, United Kingdom)*

In March 2018, the transient ASASSN-18el occurred in the nucleus of Seyfert 2 galaxy 1ES1927+654. Monitoring the source over several months our team discovered the emergence of broad Balmer emission lines, suggesting a transition from Type 2 to a Type 1 AGN on timescales consistent with the light travel time between the central black hole and the broad line region. Archival X-ray and optical observations of 1ES1927+654 in 2011 already showed an interesting AGN, which, while optically classified as a Type-2, showed an X-ray spectrum typical of an unobscured Type 1 AGN. After the recent optical outburst, the X-ray spectrum changed dramatically, with the hard X-ray corona decreasing by >2 orders of magnitude, and instead now resembles a 10^6 K thermal spectrum. In this talk, I will give an overview of our ongoing multi- wavelength follow-up with NICER, HST, XMM-Newton, NuSTAR, Keck, Swift and Las Cumbres Observatory of this unprecedented changing-look AGN. I discuss potential reasons for the onset of this accretion activity, including the tantalizing possibility that we observed the tidal disruption of a star that caused an instability in the pre-existing AGN disc and corona.

101.02 — A Careful Examination of the Physical Conditions of a Warm Corona in AGN Accretion Disks

David Ballantyne[1]

[1] *School of Physics, Georgia Institute of Technology (Atlanta, Georgia, United States)*

The origin of the soft excess in AGN X-ray spectra is unknown. The soft excess lies above the X-ray power-law, but is largely featureless and is at too large an energy to be explained by the thermal emission from the accretion disk. However, if the thermal disk spectrum passes through a warm (kT∼1 keV) and thick (τ∼10-20) scattering layer (a 'warm corona') the resulting Comptonized spectrum could fit the observed soft excess in many Seyfert galaxies. Here, I carefully consider the physical properties of the surface of an accretion disk to determine if such a warm scattering layer can be self- consistently produced given the presence of radiation from both the underlying accretion disk (shining from below) and the hard X-ray power-law (impacting from above). In addition to the radiation fields, I allow this surface layer to also be heated by varying amounts of viscous heating due to the accretion process. By keeping track of all the heating and cooling processes, I am able to self-consistently determine if this layer achieves the temperatures needed for the 'warm corona' model. I also compute the X-ray spectra produced by these layers, including the effects of X-ray reflection, to study the predicted properties of any soft excess. In this way, I can determine if the 'warm corona' model can be made physically self-consistent and still describe the AGN soft excess. I find that the 'warm corona' model can be produced self- consistently, but only for a small range of heating conditions. Therefore, if the 'warm corona' picture is correct, applying these predictions to X-ray observations will lead to insight on energy pathways within AGN accretion flows.

101.03 — AGN Obscuration, Unification and the Cosmic X-Ray Background

Roland Walter[1]*; Christos Panagiotou*[1]

[1] *Department of Astronomy, University of Geneva (Versoix, Switzerland)*

The CXB spectrum differs from the integration of the spectra of individual AGN, calling for a large population, undetected so far, of strongly obscured Compton thick AGN. Such objects are predicted by unified models, which attribute most of the AGN diversity to their inclination on the line of sight, and play an important role for the understanding of the growth of black holes in the early Universe. The fraction of obscured AGN at low redshift can be derived from the observed CXB spectrum assuming AGN spectral templates and luminosity functions. We show that high signal-to-noise average hard X-ray spectra, derived from more than a billion seconds of effective exposure time with Swift/BAT and NuStar, imply that mildly obscured Compton thin AGN feature a strong reflection and contribute massively to the CXB. A population of Compton thick AGN larger than that effectively detected is not required, as no more than 6% of the CXB flux can be attributed to them. The stronger reflection observed in mildly obscured AGN suggests that the covering fraction of the gas and dust surrounding their central engines is a key factor in shaping their appearance.

NuStar observations of AGNs in addition indicate clearly that reflection is correlated to the spectral slope in unobscured sources, these are the objects were soft lags are observed and where reflection is dominated by disk reprocessing. Instead obscured objects feature a correlation between reflection and column density characteristics of a clumpy reprocessing region located far away.

101.04 — The deepest look at the accretion process with a 2 megasecond observation of a highly variable active galaxy

William Alston[1]*; Andrew Fabian*[1]*; Douglas Buisson*[1]*; Erin Kara*[1]*; Michael Parker*[1]*; Anne Lohfink*[1]*; Phil Uttley*[1]*; Daniel Wilkins*[1]*; Ciro Pinto*[1]*; Barbara De Marco*[1]*; Edward Cackett*[1]*; Matthew Middleton*[1]*; Dom Walton*[1]*; Chris Reynolds*[1]*; Jiachen Jiang*[1]*; Luigi Gallo*[1]*; Abderahmen Zoghbi*[1]*; Giovanni Miniutti*[1]*; Michal Dovciak*[1]*; Andy Young*[1]

[1] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*

The fast timing properties of accreting black hole light curves allow us to probe the direct vicinity of black holes, the region most affected by strong gravity. We present an extensive X-ray variability analysis from the longest XMM-Newton observation taken to date, with 2 megaseconds on the highly variable Seyfert 1 galaxy, IRAS 13224-3809. This long observation has revealed new and complex underlying variability processes. We will show modelling of the coronal and reverberation delays using GR ray tracing models. This allows us to build up the most detailed picture to date of the inner X-ray emitting regions of AGN. We discuss the implication of these results for accreting sources across the mass range.

101.05 — A Multiwavelength Exploration of Sgr A*'s Event Horizon Dynamics

Daryl Haggard[1,2]; Hope Boyce[1,2]; Melania Nynka[3]
[1] *Department of Physics, McGill University (Montréal, Quebec, Canada)*
[2] *McGill Space Institute (Montreal, Quebec, Canada)*
[3] *MIT Kavli Institute for Astrophysics (Cambridge, Massachusetts, United States)*

The last century has seen exciting tests of general relativity and the LIGO-Virgo observatories have now definitively discovered black holes. And yet we are only beginning to approach the event horizon with electromagnetic observations. Sagittarius A* is one of the closest supermassive black holes targeted by the Chandra X-ray Observatory, as well as VLT's GRAVITY instrument, the Event Horizon Telescope, and many more. It thus offers an exciting opportunity for coordinated, multi-wavelength campaigns, which are poised to identify the origin of observed X-ray and IR variability, connect it to horizon-scale structure in the submm, and distinguish between competing models: hot spots, inflow/outflow, reconnection regions, shocks, or even magnetosphere gaps. I will present recent results from cross-correlation of ambitious, simultaneous time series from Chandra, Spitzer and the JVLA, as well as prospects for future discovery.

101.06 — Size of Unresolved X-ray Emission of Radio-Loud Quasars

Xinyu Dai[1]; Burak Dogruel[1]; Eduardo Guerras[1]; Christopher Morgan[2]
[1] *Department of Physics and Astronomy, University of Oklahoma (Norman, Oklahoma, United States)*
[2] *United States Navel Observatory (Annapolis, Maryland, United States)*

The origin of the unresolved X-ray emission of radio-loud quasars is still unclear, whether it resembles the corona emission from the radio-quiet counterparts or contains an unresolved jet. We present Chandra X-ray monitoring data of three of the gravitationally-lensed radio-loud quasars, MG0414+0534, Q0957+561, and B1422+231, where we detect microlensing activities in all of the systems. We also detect the characteristic FeK line in MG0414+0534 and Q0957+561. We then perform microlensing analysis to constrain the emission size. Preliminarily, we find that the microlensing source sizes scale with supermassive black hole mass $R_S \propto M_{BH}^{2/3}$, and our size constraints can be larger than the X-ray emission sizes of radio-quiet quasars. We discuss the implications on the disk-jet connection based on our size constraints.

103 — Nuclear Equation of State

103.01 — Equation of state constraints from NICER

Anna Watts[1]
[1] *University of Amsterdam (Amsterdam, Netherlands)*

One of the primary goals of NICER, the Neutron Star Interior Composition Explorer, is to measure the masses and radii of several relatively bright, thermally-emitting, rotation powered millisecond pulsars. To achieve this the NICER team is using the waveform (or pulse profile) modelling technique: exploiting the effects of General and Special Relativity on the rotationally- modulated radiation emitted from the pulsars' hot polar caps. On behalf of the team, I will review the target selection and data processing methodology, the models and statistical inference tools being used, and the process by which we have tested and verified our analysis procedures and codes. I will then present the mass-radius results obtained by the mission to date, and discuss the implications for our understanding of the ultradense matter in neutron star cores.

103.02 — Multi-messenger Neutron Star Astrophysics and Determining the Composition of the Neutron Star Core

Andrew W. Steiner[1,2]; Spencer Beloin[1]; Sophia Han[3,4]; Khorgolkhuu Odbadrakh[2]
[1] *University of Tennessee, Knoxville (Knoxville, Tennessee, United States)*
[2] *Oak Ridge National Laboratory (Oak Ridge, Tennessee, United States)*
[3] *Ohio University (Athens, Ohio, United States)*
[4] *University of California, Berkeley (Berkeley, California, United States)*

I will begin this talk by briefly describing how multi-messenger observations of neutron stars, when coupled with information from nuclear theory and nuclear structure, will provide new information about the equation of state, the composition, and the transport properties of dense matter. The tidal deformability of a neutron star is determined by the equation of state of dense matter. I will present our earlier predictions for the tidal deformability constructed from photon-based observations and show how they

were verified by GW 170817. Next, I will briefly describe some of the thorny details of how Bayesian inference is applied to this analysis, and show how we can understand the prior choices we must make. Observations of neutron star cooling are going beyond the equation of state to determine the composition of neutron stars. Assuming no exotic matter, we find that the proton-to-neutron likely exceeds 1/9 in the core of a 2 solar mass neutron star.

103.03 — Studying the Stars here on earth

Sherry Yennello[1]

[1] *Cyclotron Institute, Texas A&M University (College Station, Texas, United States)*

Heavy-ion collisions can produce nuclear material over a range of densities and proton fractions to study the nuclear equation-of-state. These measurements are enabled by accelerating nuclei to – in some cases – GeV energies and detecting the fragments that are produced from the collisions. The detectors are multi-detector arrays capable of measuring dozens of particles simultaneously from a single collision. Data rates can range up to many hundreds of collisions per second. One can either explore the characteristics of the individual fragments that are produced, often extracting particle ratios or double ratios, or correlations between the fragments – in particular transverse collective flow. From very low density to about three times normal nuclear density measurements have been made of the density dependence of the asymmetry energy. I will present an overview of how these measurements have been made and the constraints they have set on the nuclear equation-of-state.

104 — Stages of Galaxy Cluster Formation and Evolution

104.01 — The Nature of Nurture: An Optical/NIR Exploration of High-Density Environments at z>2

Brian Clark Lemaux[1]

[1] *Department of Physics, University of California, Davis (Davis, California, United States)*

The past decade has been witness to immense progress in the understanding of the early stages of cluster formation both from a theoretical and observational perspective. During this time, samples of forming clusters at higher redshift, termed "protoclusters", once comprised of heterogeneous mix of serendipitous detections or detections arising from dedicated searches around rare galaxy populations, have reached the stage where they have begun to compete with lower-redshift samples both in terms of numbers and in the homogeneity of the detection methods. Much of this progress has come from optical/near-infrared (NIR) imaging and spectroscopic campaigns designed to cover relatively large portions of the sky to exquisite depth, sampling a large number of typical galaxies at these redshifts.

In this talk I will briefly review some of the current surveys and techniques used to find and characterize proto-clusters from an optical/NIR perspective. I will then focus on observations from the VIMOS Ultra-Deep Survey (VUDS), a massive spectroscopic campaign targeting 10,000 star-forming galaxies at $2 < z < 6$, which, in conjunction with other surveys, have uncovered a large number of proto-structures that appear to resemble clusters and groups forming in the early universe. Though ostensibly a field survey, a number of factors relating to the survey itself and intrinsic to proto-structures have allowed VUDS to sample a large range of local and global densities at these redshifts. I will discuss the development of the methods for finding, confirming, and characterizing proto-clusters and proto-groups in the context of VUDS including new techniques and tools developed specifically for these purposes. Several case studies of spectroscopically confirmed massive proto-clusters will be presented, focused both on the diversity of their global properties and that of their member populations. I will also discuss preliminary work on the full ensemble of VUDS proto-structures as well as measurements of the star formation rate-density and color-density relations at these redshifts.

104.02 — Feeding the Beasts: Star formation and molecular gas inside of galaxy clusters.

Tracy Webb[1]

[1] *Department of Physics, McGill University (Mont-Royal, Quebec, Canada)*

The study of molecular gas in distant galaxies is a burgeoning field. Here we present the results of several studies of the molecular gas in cluster galaxies at high ($z > 1$) redshift clusters. The clusters are selected in the optical/NIR through the red-sequence technique of the SpARCS survey. Not only do these studies offer the chance to understand the effect of the cluster environment on the gas content of member galaxies, but the efficient multiplexing of cluster fields provides for large samples of massive galaxies. Our results reveal cluster galaxies at high redshift, including the Brightest Cluster Galaxies, are replete with molecular gas. Many of the galaxies have spatially resolved kinematic information and exhibit velocity gradients, multiple components, and tentative gas tails. We discuss these results in the context of galaxy stellar mass assembly in dense cluster environments.

104.03 — Unveiling galaxy cluster candidates at z>2 with Planck and NASA's Great Observatories; Prospects for JWST, Euclid, WFIRST, Athena and Lynx.

Herve Dole[1,2]
[1] *IAS, Univ. Paris-Sud - Paris-Saclay (Orsay, France)*
[2] *IAS - Institut d Astrophysique Spatiale - CNRS univ Paris-Sud univ Paris-Saclay (Orsay, France)*

I will review the scientific motivations for studying high-redshift (z>1.5) galaxy clusters and the current status of detections. I will higlight the 3 main selections of high-z (proto-)galaxy clusters (by stellar mass, by hot gas, by star-formation rate) and focus on the Planck selection: the SPHerIC sample (Spitzer, Planck, Herschel Infarred Clusters). I will then open the perspectives with the forthcoming facilities like ESA's Euclid and Athena, and NASA's ESA's JWST, and NASA's WFIRST and Lynx.

104.04 — Overview of High-Redshift SZ Cluster Surveys

Lindsey Bleem[1]
[1] *Department of High Energy Physics, Argonne National Laboratory (Lemont, Illinois, United States)*

Over the past decade wide-area high-resolution cosmic microwave background (CMB) surveys conducted by the South Pole Telescope, Atacama Cosmology Telescope, and *Planck* have enabled the discovery of 1000s of clusters via the Sunyaev-Zel'dovich (SZ) effect, including over 100 clusters at z>1. These massive clusters have proven to be valuable resources for astrophysical and cosmological studies. In this talk I will highlight recent and projected results from these SZ cluster surveys, particularly focusing on (1) multi- wavelength characterization of z>1 clusters from the SPT-SZ survey, (2) the discovery of new high-redshift systems with the recently completed SPTpol survey, and (3) projections for upcoming cluster samples from current and proposed (e.g., CMB-S4) SZ surveys. Beyond discovering thousands of high- redshift systems, these surveys will also provide mass calibration for cluster samples via weak lensing of the CMB.

105 — Chandra at 20

105.01 — The Impact of Chandra on Black Hole Astrophysics

Christopher Reynolds[1]
[1] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*

The ubiquitous nature of winds from black hole accretion disks; the complex radiatively-inefficient accretion flow around our Galactic Centre black hole; robust measurements of spin in stellar mass black holes; the physics of relativistic jets; cluster-scale AGN feedback — these are just some of the issues in black hole astrophysics that have been completely transformed by the high-spatial and high-spectral capabilities of Chandra. This talk will present a brief tour of the transformative effect that Chandra had on the field of black hole astrophysics and will look forward to the next generation of X-ray facilities.

105.02 — Chandra's Stars

Thomas Ayres[1]
[1] *Center for Astrophysics & Space Astronomy, University of Colorado (Boulder, Colorado, United States)*

Stars are the powerhouses and chemical factories of galaxies; hosts of exoplanets that in some cases might harbor life. It is not surprising, then, that stars are principal objects of interest to astronomers. What *is* surprising: normal stars are frequent targets of kilo-volt X-ray observatories, given that stellar surfaces have temperatures no more than 0.01 keV (extreme O-type stars, at that). Nevertheless, hydrodynamic and magnetic phenomena on stars conspire to create conditions hundreds of times hotter than the tepid photospheres, to drive copious X-ray emissions in many cases. Examples include: radiative instability shocks in the warm, fast winds of early-type supergiants; accretion splash-down spots on protostars; magnetic coronae of Main-sequence cool stars; and high-energy flares from a wide variety of objects. *Chandra* has played a key role in stellar X-ray studies over the past two decades because, among many examples, the high spatial resolution can associate X-ray sources with optical and IR counterparts in crowded star-forming regions; the low-resolution CCD spectra can characterize faint point sources, such as planet-hosts and young embedded protostars; and the transmission gratings can diagnose plasma conditions in shocked stellar winds, T-Tauri accretion columns, and hyperactive stellar coronae.

In addition to a general overview of Chandra's impact on stellar astronomy, the presentation will mention long-term coronal activity cycles of the two sun-like stars of the nearby Alpha Centauri triple system, with relevance to planetary habitability; and the temporal behavior of serendipitous sources in the Chandra HRC-I field around Alpha Cen, as a guide to what might be anticipated in large-area X-ray surveys of the future.

105.03 — New perspectives on the interstellar medium enabled by Chandra

Lia Corrales[1]
[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

Chandra's High Energy Transmission Grating (HETG) instrument has accumulated a rich dataset of high resolution spectra from bright Galactic X-ray binaries. The light from these sources is subject to absorption by all abundant metals in the interstellar medium (ISM), whether they are in gas or dust form. Measuring the depth and shape of the photoelectric edges in these spectra will ultimately enable determination of the absolute abundances of gas and solid phase metals in the ISM, a task that can only be done in the 0.2-10 keV band. X-ray absorption fine structure (XAFS) in the photoelectric edge also reveals dust grain mineralogies and grain sizes. I will review modern results and show how Chandra's perspective on the ISM has motivated fundamental physics research, in both theory and laboratory experiments. Finally, I will review how future X-ray observatory technology will probe the fundamental nature of the ISM, in our Galaxy and beyond.

105.04 — Constraining the seeds of super-massive black holes with high-res X-ray imaging observations

Elena Gallo[1]
[1] *University of Michigan (Ann Arbor, Michigan, United States)*

After reviewing the key contributions from Chandra to further our understanding of super-massive black hole accretion across cosmic time, I will focus on the properties of highly sub-Eddington black hole accretion in the nearby universe, both with Chandra as well as next generation high spatial resolution X-ray mission concepts, such as AXIS and Lynx. I will discuss the feasibility of a few per cent level measurement of the local black hole occupation fraction through high-resolution imaging observations of local volume galaxies.This measurement aims to establish a benchmark for any model which aims to reproduce the assembly of galaxies and their nuclear black holes. Concurrently, it yields an independent constraint to black hole seed formation models, complementing orthogonal efforts which will be carried out at high red-shifts.

105.05 — High Resolution Spectroscopy with Chandra

Frits Paerels[1]
[1] *Department of Astronomy, Columbia University (New York, New York, United States)*

Chandra (and XMM-Newton) opened up high resolution spectroscopy as a 'routine' tool of investigation in high energy astrophysics. I will highlight some of the most striking results, emphasizing results that point the way to use of the diffraction grating spectrometers that will remain important and unique even with the advent of imaging microcalorimeter-based spectrometers.

106 — AGN Poster Session

106.01 — Time-Domain Signatures of Supermassive Black Hole Binaries

Kevin Whitley[1]*; Kayhan Gultekin*[1]*; Mateusz Ruszkowski*[1]
[1] *University of Michigan (Ann Arbor, Michigan, United States)*

Modern observational techniques and technologies are insufficient for identifying sub-parsec separation supermassive black hole (SMBH) binaries, despite their paramount importance to the evolution of SMBHs and the galaxies which host them. Current methods focus on identifying multiple absorption lines in AGN jets or spectrally distinct Broad Line Regions, but these are still unable to probe the extremely close separations relevant to gravitational wave explorations. In this talk, we focus on the potential for time-domain identification of sub-parsec SMBH binaries. We use hydrodynamics simulations of a close-separation, low mass-ratio (q « 1) SMBH binary to explore the characteristic frequencies with which optical, UV, and X-ray emissions will vary in these sources. This talk will detail the methods employed in these simulations and their analysis and will present preliminary results demonstrating proof-of-concept for time-domain SMBH binary identification.

106.02 — Can we measure black hole spin in quasar 4C 74.26?

Panayiotis Tzanavaris[1]; Tahir Yaqoob[3]; Andrew Ptak[2]; Stephanie LaMassa[4]; Mihoko Yukita[5]
[1] *NASA-GSFC/CRESST/UMBC (Silver Spring, Maryland, United States)*
[2] *NASA/GSFC (Greenbelt, Maryland, United States)*
[3] *NASA-GSFC/CRESST/UMBC/JHU (Greenbelt, Maryland, United States)*
[4] *STScI (Baltimore, Maryland, United States)*
[5] *NASA-GSFC/JHU (Greenbelt, Maryland, United States)*

We modeled broadband X-ray spectra from *Suzaku* and *NuSTAR* with MYTORUS, which self-consistently accounts for Fe Kα line emission, as well as direct and reflected continuum emission, from finite column density matter. A narrow unresolved Fe Kα emission line originating in an X-ray reprocessor with solar abundance far from the central supermassive black hole (SMBH) is sufficient to produce excellent fits for all spectra. For the first time, we are able to measure the global, out of the line-of-sight column density to be in the range $\sim$1.5 to $\sim$2.9 × 10^{24} cm^{-2}, i.e. in the Compton thick regime, while the line-of-sight column density is Compton thin in all observations. Unlike the great majority of previous analyses that modeled these data with a relativistically broadened Fe Kα emission line, our results suggest that the reprocessed X-ray emission present in these 4C 74.26 X-ray data does not arise in the inner accretion disk and thus is not useful for constraining SMBH spin.

106.03 — The Accretion History of AGN: Supermassive Black Hole Population Synthesis Model

Tonima Tasnim Ananna[1]
[1] *Department of Physics, Yale University (New Haven, Connecticut, United States)*

As matter accretes onto the central supermassive black holes in active galactic nuclei (AGN), X-rays are emitted. We present a population synthesis model that accounts for the summed X-ray emission from growing black holes; modulo the efficiency of converting mass to X-rays, this is effectively a record of the accreted mass. We need this population synthesis model to reproduce observed constraints from X-ray surveys: the X-ray number counts, the observed fraction of Compton-thick AGN [log (NH/cm−2) >24] and the spectrum of the cosmic X-ray background (CXB), after accounting for selection biases. Over the past decade, X-ray surveys by XMM-Newton, Chandra, NuSTAR and Swift-BAT have provided greatly improved observational constraints. We find that no existing X-ray luminosity function (XLF) consistently reproduces all these observations. We take the uncertainty in AGN spectra into account, and use a neural network to compute an XLF that fits all observed constraints, including observed Compton-thick number counts and fractions. This new population synthesis model suggests that, intrinsically, 50±9% (56±7%) of all AGN within z ∼ 0.1 (1.0) are Compton-thick.

106.04 — The joint fluctuations of the CIB and CXB: new ideas, new results and future developments

Nico Cappelluti[1]
[1] *University of Miami (Coral Gables, Florida, United States)*

The joint fluctutions the CIB and CXB are in excess with respect to what expected from know emitters. Theoritical works proposed that the signal was produced by early Direct Collapse Black Holes. However, after in depth investigations other scenarios seem to offer promising solutions. Taking advantage of 13 Ms Chandra observations and deep Spitzer data, I am presenting a) The first time measured SED of the joint CIB and CXB fluctuations and, b) a new model of early populations and of galactic scattering that can finally explain this signal. I willl finally show how eROSITA, Athena and EUCLID will contribute to solve this problem.

106.05 — AGN Synthesis of the Cosmic X-ray Background in the Era of *NuSTAR*

Ryan C. Hickox[1]; Mackenzie Jones[2]; Tonima Tasnim Ananna[3]
[1] *Department of Physics and Astronomy, Dartmouth College (Hanover, New Hampshire, United States)*
[2] *Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*
[3] *Yale University (New Haven, Connecticut, United States)*

The origin of the cosmic X-ray background (CXB) has been a central problem in high-energy astrophysics since its discovery by Riccardo Giacconi and colleagues in rocket flights in the 1960's. The CXB is now known to be comprised mainly of emission from individual active galactic nuclei (AGN), the majority of which must be heavily obscured in order to reproduce the observed peak of the background at $\sim$30 keV. With the launch of *NuSTAR*, we can now directly probe the emission from individual AGN at these peak energies, and begin to perform direct measurements of the synthesis of the CXB. I will present the results of a stacking analysis of AGN in the *NuSTAR* extragalactic surveys, and show that known AGN detected by *NuSTAR* or *Chandra* account for the majority of the CXB at energies up to 24 keV. I will compare these results to the predictions of recent CXB synthesis models (one based on a complete treatments of the X-ray AGN population, another utilizing semi-numerical prescription of galaxy and black hole formation). These CXB synthesis models show excellent agreement with the *NuSTAR* observations, providing an important step toward a complete understanding of the origin of the CXB. This work was supported in part by NASA through award numbers NNX15AU32H and NNX15AU32H, and the National Science Foundation through award number 1554584.

106.06 — A universal model of black hole accretion uncovering AGN in the Cosmic X-ray background

Mackenzie Jones[1]
[1] *Center for Astrophysics | Harvard & Smithsonian (Malden, Massachusetts, United States)*

From observations of active galactic nuclei (AGN) we may improve our understanding of the growth of black holes across cosmic time and their impact on their host galaxies, but observations alone may be limited by complex biases. Here I will present our results from modeling the whole AGN population while accounting for observational biases. I will begin by showing that the Eddington ratio distribution for optically-selected AGN is consistent with a broad power-law that is independent of host galaxy type or age. This broad Eddington ratio distribution is also observed in the X-rays, suggesting that a universal Eddington ratio distribution may be enough to describe the full AGN population. From these results, I have developed a new semi-numerical galaxy formation simulation with a straightforward prescription for AGN accretion. I will show that our simple model for AGN accretion can broadly reproduce the observed properties of X-ray AGN host galaxies and halos. I also find a trend between Eddington ratio distribution and redshift, consistent with the behavior predicted by hydrodynamic simulations. Finally, I will describe a new synthesis model for the Cosmic X-ray Background based on this semi-numerical model and present our results investigating the physical properties of the AGN population and their host galaxies and halos that contribute to this background emission.

106.07 — The Unresolved Cosmic X-ray Background as Measured by NuSTAR

Steven Rossland[1]*; Daniel Wik*[1]
[1] *University of Utah (Salt Lake City, Utah, United States)*

The extragalactic cosmic X-ray background emission (CXB) in the "hard" band (~3-300 keV) is dominated by AGN, which contains information about the accretion history over all cosmic time. While previous X-ray background missions agree on the overall shape of the CXB, the absolute calibration between each of these missions can vary from ~10-40%, due to a lack of an absolute X-ray calibration source. Furthermore, a complete census of the AGN populations that contribute to the peak emission in this range (20-30keV) can be difficult to measure due to the hydrogen column density that can surround and obscure some of the AGN. NuSTAR, with a reliable sensitivity from 3-40 keV, is well suited for making these measurements, due to an absence of shielding around the mast, which allows stray light to leak onto the detectors. This stray light process, which collects ~10 times the number of photons than the focused portion, is almost entirely from the CXB. By understanding how these photons are modulated by the geometry of the spacecraft, we can accurately and precisely measure the normalization of the CXB by eliminating the dependence on the calibration of the mirrors. The difficulties in making such a measurement lie with eliminating all other contributing sources such as instrumental, solar, and other x-ray sources that contaminate our measurements. Using ~50 Ms of observational and ~15 Ms of earth occulted data from NuSTAR's archive, we present a preliminary measurement of the CXB through the methods described.

We acknowledge support from the NuSTAR mission and from NASA Astrophysics Data Analysis Program grant 16-ADAP16-0118.

106.08 — Gamma-ray Analysis of the Most Energetic Blazars to Probe the Cosmos

Ryan Hsu[1]*; Cindy Wang*[2]
[1] *Gunn High School (Palo Alto, California, United States)*
[2] *The Harker School (San Jose, California, United States)*

The extragalactic background light (EBL) is all the accumulated infrared and optical radiation in the universe produced by stars, dust, and active galactic nuclei (AGNs). Studying EBL is important for understanding the energetics of the universe and its evolution. Directly measuring EBL is difficult due to the contribution of zodiacal light that outshines the EBL in the foreground. We present a method of indirect EBL measurement using gamma- ray emissions of the brightest AGNs, blazars, to probe the EBL density along the line of sight. This project utilizes ten years of LAT data, the largest dataset ever used for an EBL study. Gamma-ray photons are a viable probe for EBL due to their interactions: when a gamma-ray photon collides with another photon, they annihilate in a process called pair production, forming a positron and electron pair and causing absorption that alters the observed spectrum. For certain blazars, the observed spectrum did not validate any existing EBL models. This warrants additional analysis as it might indicate local EBL anisotropy. To constrain the parameters of the EBL model, we present a complex multi-step likelihood analysis of the deviant sources to produce gamma-ray spectra, leveraging the Fermi Science Tools created by NASA for the Fermi-LAT mission. The likelihood analysis attributes photons to known sources from the FL8Y catalog, a recently released database of all known gamma-ray sources. The developed method is applicable to hundreds of LAT gamma-ray sources and we hope that it will provide the best gamma-ray based EBL measurement to date.

106.09 — Using Machine Learning and Swift-XRT to Characterize likely X-ray Counterparts to Fermi Unassociated Sources

Amanpreet Kaur[1]; Abraham D. Falcone[1]; Michael Stroh[2]

[1] *Department of Astronomy and Astrophysics, Pennsylvania State University (State College, Pennsylvania, United States)*

[2] *The University of New Mexico (Albuquerque, New Mexico, United States)*

The Fermi Gamma Ray Observatory has revolutionized gamma-ray astronomy by discovering thousands of sources since its launch in 2008. However, the unidentified population of these sources in the Fermi catalogs is still substantial, e.g. one-third of the Fermi sources in the 3FGL catalog are unidentified. Swift-XRT observations of these Fermi unassociated fields have found possible X-ray counterparts in ~30% of these Fermi unassociated uncertainty regions, and approximately half of these sources were previously uncatalogued in either radio/optical/X-ray catalogs. The main objective of this work is to identify the nature of these possible counterparts, utilizing the properties of known Fermi sources coupled with the X-ray source properties. The majority of the known sources in the Fermi catalogs are blazars, which constitute the bulk of the extragalactic gamma-ray source population. The galactic population, on the other hand, is dominated by pulsars. Overall, these two categories constitute the majority of all gamma- ray objects. Blazars and pulsars occupy different parameter space when X-ray fluxes are compared with various gamma-ray properties. In our work, we utilize the X-ray observations performed with the Swift-XRT for the unknown Fermi sources and compare the X-ray and gamma-ray properties of possible X-ray associations in order to differentiate between blazars and pulsars. We then employ two machine learning algorithms to our high signal-to-noise ratio sample (121 X-ray sources that are likely to be associated with the gamma-ray source) identifying them with a pulsar or a blazar type. From this sample, we find that ~80% of the sources are likely blazars and ~3% are likely pulsars, at the 90% confidence interval. There are also a handful of new X-ray associations which are not clearly identified as either pulsars or blazars.

106.10 — Measuring the EBL using GeV and TeV observations

Abhishek Desai[1]; Kari Helgason[3]; Marco Ajello[1]; Alberto Dominguez[4]; Vaidehi S. Paliya[5]; Justin Finke[2]; Dieter Hartmann[1]

[1] *Clemson University (Central, South Carolina, United States)*

[2] *US Naval Research Laboratory (Washington, District of Columbia, United States)*

[3] *University of Iceland (Taeknigardur, Iceland)*

[4] *Universidad Complutense de Madrid (Madrid, Spain)*

[5] *Deutsches Elektronen Synchrotron DESY (Zeuthen, Germany)*

The collective emission of all sources over the history of the universe is encoded in the intensity of the extragalactic background light (EBL), the diffuse cosmic radiation field at ultraviolet, optical, and infrared wavelengths. A powerful technique to study the EBL is through the imprint it leaves in the spectra of distant gamma-ray sources via the photon-photon interaction. In this talk, I will report on the first unprecedented measurement of the EBL, in the UV, optical and IR wavelength regime, using GeV data from the Large Area Telescope on board the Fermi Gamma-ray Space Telescope and TeV data from ground based telescopes (like HESS, MAGIC, and VERITAS). I will also talk about the future implications of the work including improvements which would be seen using observations from future programs like CTA.

106.11 — Recent Highlights from the VERITAS Extragalactic Gamma-ray Observations

Amy Furniss[1]

[1] *Department of Physics, California State University, East Bay (Hayward, California, United States)*

The Very Energetic Radiation Imaging Telescope Array System (VERITAS) is a ground-based gamma-ray observatory consisting of an array of four atmospheric Cherenkov telescopes located in southern Arizona. This instrument observes the gamma-ray sky at energies above 100 GeV. The majority of the sources detected by VERITAS are active galactic nuclei, with gamma-ray emission originating from the relativistic jets. Nearly 5000 hours of observations of active galactic nuclei (AGN) have been performed over the last 10 years. These observations have led to 36 detections up to the redshift of 0.9, including the FRI radio galaxy 3C 264, currently the most distant radio galaxy yet detected. In an attempt to understand the origin of the gamma-ray emission, many of the VERITAS observations of extragalactic sources are paired with simultaneous observations at X-ray energies. This talk will present an overview of the extragalactic discoveries resulting from VERITAS observations and the insights provided by the multi-wavelength campaigns.

106.12 — Initial stages of black hole activity probed with X-rays from young extragalactic radio sources

Malgosia Sobolewska[1]; Aneta Siemiginowska[1]; Matteo Guainazzi[2]; Martin Hardcastle[3]; Guilia Migliori[4]; Luisa Ostorero[5]; Lukasz Stawarz[6]

[1] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

[2] *ESA/ESTEC (Noordwijk, Netherlands)*

[3] *University of Hertfordshire (Hatfield, United Kingdom)*

[4] *INAF (Bologna, Italy)*

[5] *INFN (Torino, Italy)*

[6] *Jagiellonian University (Krakow, Poland)*

There is growing evidence that the onset of black hole (BH) activity is accompanied by a formation of a radio jet. Jet's impact on BH surrounding and further BH feeding are believed to be essential to the AGN-galaxy feedback idea. Highly relativistic plasma contained within young radio lobes and shocks due to jet expansion are expected to generate high energy radiation. However, observing young radio jets at high energies has been challenging as they proved to be relatively faint. Here we discuss the most recent results for the four Compact Symmetric Objects (CSO; radio structure sizes 2-16 pc, ages 100-400 years) based on the new high quality broad-band radio-to-gamma-ray spectral energy distributions including Chandra, XMM-Newton (AO17), NuSTAR (AO4) and Fermi/LAT data. For the first time, we have now means to test theoretical scenarios for the high energy emission of the youngest radio jets (radio lobes origin, shocked ISM, jet, disk corona). We were able to refute the radio lobes origin in at least one source, confirm the Compton thick nature of CSO J1511+0518, and collect evidence that PKS 1843+356 is most likely a blazar and not a CSO. These findings provide further evidence in favor of the Compton thick/thin dichotomy of the CSO environment that we have recently discovered. This dichotomy may suggest that X-ray obscured CSOs have smaller radio sizes than X-ray unobscured CSOs with the same radio power, and indicate that the environment may play a crucial role in regulating the early growth of the radio jets. Importantly, X-ray properties of the Compton thick CSO sub-population, in conjunction with recent developments in the optical/IR and radio bands, offer new insight for understanding the structure and size of the AGN obscuring torus, as they probe the X-ray emission/absorption/scattering features on the torus (parsec) scale. We discuss the implications of our results for the high energy emission models of radio jets, the earliest stages of the radio source evolution, diversity of the medium in which the jets expand, and jet-galaxy co-evolution.

106.13 — Efficient non-thermal particle acceleration mediated by the kink instability in jets

E. Paulo Alves[1]; Jonathan Zrake[2]; Frederico Fiuza[1]

[1] *High Energy Density Science, SLAC National Accelerator Lab (Menlo Park, California, United States)*

[2] *Columbia University (New York, New York, United States)*

Jets emanating from active galaxies are among the most powerful particle accelerators in the universe. They shine across the entire electromagnetic spectrum, and are candidate sources of ultrahigh-energy cosmic rays. Yet, the dominant mechanisms responsible for particle acceleration in these systems are not well understood. Global magnetohydrodynamic simulations suggest that the development of the current-driven kink instability (KI) can play an important role in the dissipation of the jet's internal magnetic field near recollimation regions, but it remains unclear if such process could lead to efficient non-thermal particle acceleration. We have performed large-scale 3D particle-in-cell simulations to investigate the self-consistent particle acceleration dynamics associated with the development of the KI in conditions relevant to magnetized relativistic jets. We find that the development of the KI mediates the efficient conversion of the magnetic energy into high-energy particles. We show that non-thermal particles are accelerated by a large-scale inductive electric field that develops throughout the unstable region during the nonlinear stage of the KI. The acceleration process is made efficient by the highly tangled magnetic field structure that arises in the nonlinear phase, which enables rapid curvature drifts across magnetic field lines and along the inductive electric field. This results in the development of a power-law energy tail that contains 50% of the initial magnetic energy, and that extends to the confinement energy of the jet. By scaling our results to the conditions of bright knots in AGN jets, such as HST-1 and Knot A in M87, we show that this mechanism can account for the spectrum of synchrotron radiating particles, and offers a viable means for accelerating ultra-high energy cosmic rays.

106.14 — Time-Dependent, Multi-Wavelength Models for Active Flares of Blazars

Matthew Baring[1]; Markus Boettcher[2]
[1] *Department of Physics and Astronomy, Rice University (Houston, Texas, United States)*
[2] *North-West University (Potchefstroom, South Africa)*

Jets in blazars are an excellent forum for studying acceleration at relativistic shocks using the highly-variable emission seen across the electromagnetic spectrum. Our recent work on combining multi-wavelength leptonic emission models with complete simulated distributions from shock acceleration theory has resulted in new insights into plasma conditions in blazars. This has demonstrated the ability to infer the cyclotron frequency, the plasma density and thus also the Alfven speed, thereby determining the rapidity of particle energization. An important inference was that turbulence levels decline with remoteness from jet shocks. In this paper, we deliver new results from our recent extension of this program to a two-zone, time-evolving construction, modeling together both extended, enhanced emission states from larger radiative regions, and prompt flare events from compact acceleration zones. These are applied to the Fermi-LAT and TeV blazars 3C 279 and Mrk 501. With impulsive injection episodes from the shock zone, as the acceleration first proceeds and then abates, the radiative simulations obtain spectral hysteresis in the hardness-flux diagram in all wavebands. For 3C 279, an LBL blazar, while model radio and X-ray synchrotron flares a temporally correlated, there is a lag in both bands relative to GeV gamma-rays and optical emission on timescales of several hours. This is governed by the short cooling time associated with the bright external Compton signal. The results are interpreted in the light of the shock acceleration paradigm, identifying potential observational diagnostics.

106.15 — Confronting UFO Models through Correlation Analysis in AGNs

Keigo Fukumura[1]; Demos Kazanas[6]; Chris Shrader[6,3]; Ehud Behar[4]; Francesco Tombesi[2,5]; Ioannis Contopoulos[7]
[1] *Department of Physics and Astronomy, James Madison University (Harrisonburg, Virginia, United States)*
[2] *University of Maryland (College Park, Maryland, United States)*
[3] *CUA (Washington DC, District of Columbia, United States)*
[4] *Technion (Haifa, Israel)*
[5] *University of Roma Tor Vergata (Roma, Italy)*
[6] *NASA/GSFC (Greenbelt, Maryland, United States)*
[7] *Academy of Athens (Athens, Greece)*

Blueshifted absorption features at near-relativistic velocities (v~0.1c), known as ultra-fast outflows (UFOs), seem to be ubiquitously present in X-ray spectra of many AGN populations. In two near-Eddington sources, PDS 456 and IRAS 13224-3809, the detected UFO property (e.g. column and velocity) is conjectured to exhibit likely correlations with X-ray luminosity (Lx) that was attributed to variations in radiation pressure as Lx varies. In this work, we show that magnetically-driven winds of Compton-thick plasma can produce similar correlations in which radiation plays little role in shaping outflows. Utilizing semi-analytic magnetohydrodynamic (MHD) calculations of winds that is coupled to photoionization process with xstar, we model Fe XXVI UFO spectrum and its predicted correlations for different Lx. Our calculations imply that certain UFO correlations can be expected depending on the luminosity scaling with accretion rate.

106.16 — From AGN Warm Absorbers to the Blazar Sequence

Demosthenes Kazanas[1]; Stella Boula[2]; Apostolos Mastichiadis[2]
[1] *Astrophysics Science Division, NASA/Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[2] *University of Athens (Athens, Greece)*

One of the discoveries of ASCA, Chandra and XMM-Newton has been the unbiquitous presence of blue-shifted absorption features in the AGN (both Radio Quiet and Radio Loud) X-ray spectra (Warm Absorbers), implying the presence of ouflows, ranging in velocities from tens of thousands of km/s to just a few hundred km/s and of ionization states ranging from highly ionized to neutral iron. Global fits of the plethora of transitions has shown the outflow column to be independent of their ionization state, implying a specific density profile for these outflows; the favored profile has a form n(r) $\sim r^{-p}$ with p $\sim$ 1.0 . This p-value is inconsistent with that expected in radiative driven winds, but consistent with MHD driven winds from the entire disk domain, spanning a range of 10^6 in radius, in agreement with the observed range of velocities. The specific wind profile and the wind magnetic field structure, provide a well defined photon-to-magnetic field energy densities out to distances 1-10 pc: They both drop like $1/r^2$, with normalizations proportional to $(mdot)^2$ and mdot respectively (mdot <1, is the Eddington normalized wind/accretion mass flux). Therefore, on the frame of a jet of Lorentz factor Γ along the AGN axis, the photon density will be $\rho(rad) \sim (mdot)^2 \Gamma^2$, while that of the magnetic field $\rho(B) \sim B^2 \sim$ mdot. Therefore, one expects Compton dominance for $mdot^2\Gamma^2 >$ mdot or for $\Gamma^2 > 1/mdot$. We present detailed blazar SED models that can reproduce the entire Blazar sequence by varying this one parameter, namely mdot, taking into account the synchrotron, inverse Compton losses and particle escape from the system to determine the maximum value of the electron distribution break responsible for the frequency of synchrotron and Compton peak luminosities. Our results are consistent with the findings of more than 1000 blazars by Fermi.

106.17 — Investigating the Relationship Between VLBI Jet Speeds and the Kinetic Power of the Jet

Mary Keenan[1]; Eileen Meyer[1]
[1] Department of Physics, University of Maryland, Baltimore County (Baltimore, Maryland, United States)

Radio-loud AGN have large-scale jets of relativistic plasma propagating away from the central accreting black hole. Slowed plasma from these jets accumulates into giant radio-emitting lobes on either side of the host galaxy over the lifetime of the jet, resulting in a spatially extended, isotropic synchrotron emission which dominates at low frequencies. The other prominent source of emission at low frequencies is due to the point source core itself, which typically dominates the spectrum at higher frequencies. This emission can be enhanced by orders of magnitude due to relativistic beaming along the jet axis and so it is difficult to estimate the intrinsic luminosity. The core and the lobe emission can be separated through decomposing the low frequency spectrum. Once separated, the extended emission can be used as a proxy for jet power, as it has been shown to correlate with the kinetic power of the jet (Cavagnolo et. al 2010, etc.) and serves as a viable method of estimating it. We have compiled a large catalog of jet proper motions measured by VLBI, to investigate the relation between the apparent speeds and this kinetic jet power. We will present preliminary evidence that the kinetic power of the jet has an intrinsic connection with the Lorentz factor of the underlying flow within the jet, which is apparent through the apparent speeds of plasma being ejected from the core, as measured by VLBI. We are using a population modeling approach to determine whether we are able to quantify a characteristic value of the Lorentz factor, based on the kinetic power.

106.18 — A stratified ultrafast outflow in 1H0707-495?

Peter Kosec[1]; Ciro Pinto[2,1]; Andrew Fabian[1]; Dom Walton[1]
[1] Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)
[2] European Space Agency / ESTEC (Noordwijk, Netherlands)

Ultrafast outflows (UFOs) have recently been found in the spectra of a number of active galactic nuclei (AGN) and are strong candidates for driving AGN feedback. 1H0707-495 is a highly accreting narrow line Seyfert 1 in which previous studies found evidence of blueshifted absorption at 0.1-0.2c. We perform a flux-resolved analysis of the full XMM-Newton dataset on this AGN using both CCD and grating data and focus on the low flux spectrum. We find strong evidence for a UFO in absorption at $\sim$0.13c, with an ionisation parameter $\log(\xi\ /\mathrm{erg\ cm\ s^{-1}}) = 4.3$. Surprisingly, we also detect blueshifted photoionised emission, with the velocity increasing at higher ionisation states, consistent with a trend that has been observed in the UV spectrum of this object. The bulk of the X-ray emitting material is moving at a velocity of 8000 km/s, with ionisation parameter $\log(\xi\ /\mathrm{erg\ cm\ s^{-1}}) = 2.4$. The wind kinetic power inferred from the UFO absorption is comparable to that of the UV and X-ray emission features despite their different velocities and ionisation states, suggesting that we are viewing an energy-conserving wind slowing down and cooling at larger distances from the AGN.

106.19 — Nature of AGN Feedback: Testing Numerical Models with Chandra Observations

Yuan Li[1]; Corey Brummel-Smith[2]; Irina Zhuravleva[3]; Daisuke Nagai[4]
[1] Department of Astronomy, University of California, Berkeley (Berkeley, California, United States)

[2] Georgia Institute of Technology (Atlanta, Georgia, United States)
[3] The University of Chicago (Chicago, Illinois, United States)
[4] Yale University (New Haven, Connecticut, United States)

It is widely accepted that AGN feedback is the key to solving many problems related to galaxy evolution, including the cooling flow problem in cool-core galaxy clusters. While numerical simulations of AGN feedback in galaxy clusters have achieved great success, there seems to be tension between simulations and observations regarding the level of turbulence in the ICM generated by AGN. In addition, many different models are able to suppress cooling and there is not a satisfactory way to discriminate between them. On the other hand, sophisticated methods have been developed to extract information from the X-ray observations of cluster centers, and have helped interpret the level of turbulence and the nature of perturbations in real clusters. To better test numerical models and better understand the observations, we first generate mock X-ray observations of state-of-the-art numerical simulations of AGN feedback in cool-core clusters. We then analyze the nature of perturbations, both directly using the 3D simulation data and using the mock images, and compare the simulated clusters with the observed ones. We also compare results from analyzing the same simulated cluster with different exposure time and viewing angles, and try to test the robustness and understand the possible biases of the observational analysis.

106.20 — Reconnection and Associated Flares in Global Relativistic Jets Containing Helical Magnetic Fields with PIC Simulations

Kenichi Nishikawa[1]; Yosuke Mizuno[2]; Ioana Dutan[3]; Jacek Niemiec[4]; Jose Gomez[5]; Nicholas MacDonald[6]
[1] Alabama A&M University (Normal, Alabama, United States)
[2] Institute for Theoretical Physics, Goethe University (Frankfurt am Main, Germany)
[3] Institute of Space Science (Magurele, Romania)
[4] Institute of Nuclear Physics PAN (Krakow, Poland)
[5] Instituto de Astrofísica de Andalucía (Granada, Spain)
[6] Max-Planck-Institut fuer Radioastronomie (Bonn, Germany)

The discovery by Advanced LIGO/Virgo of gravitational waves from the binary neutron star (BNS) merger GW170817 triggered sequential observations of the electromagnetic counterparts, which has opened the era of multi-messenger astronomy. These multi-frequency observations provide us profound information to investigate the processes from the generation of gravitational wave, associated relativistic jets and merger ejecta, and consequently radiation from the interaction of jets and ejecta with interstellar medium. The investigation of these phenomena requires extensive and systematic theoretical and computational research with various observations.

In the study of relativistic jets one of the key open questions is their interaction with the environment on the microscopic level. Here, we study the initial evolution of both electron–proton and electron–positron relativistic jets containing helical magnetic fields, focusing on their interaction with an ambient plasma. We have performed simulations of "global" jets containing helical magnetic fields in order to examine how helical magnetic fields affect kinetic instabilities such as the Weibel instability, the kinetic Kelvin-Helmholtz instability (kKHI) and the Mushroom instability (MI) using a larger jet radius. In our initial simulation study these kinetic instabilities are suppressed and new types of instabilities can grow. In the electron-proton jet simulation a recollimation-like instability occurs near the center of jet. In the electron-positron jet simulation mixed kinetic instabilities grow and the jet electrons are accelerated. The evolution of electron-ion jets will be investigated with different mass ratios. Simulations using much larger systems are required in order to thoroughly follow the evolution of global jets containing helical magnetic fields. We also investigate mechanisms of flares possibly due to reconnection.

106.21 — Deflection of the jets of Cygnus A from the intracluster medium

Paul Nulsen[1,2]; Amalya Johnson[1,3]; Bradford Snios[1]; Ralph P. Kraft[1]; John ZuHone[1]; Chris Carilli[4]; Michael Wise[5]; Brian McNamara[6]
[1] HEAD, Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)
[2] ICRAR, University of Western Australia (Crawley, Western Australia, Australia)
[3] Columbia University (New York, New York, United States)
[4] NRAO (Socorro, New Mexico, United States)
[5] SRON (Utrecht, Netherlands)
[6] University of Waterloo (Waterloo, Ontario, Canada)

The Fanaroff-Riley class II radio galaxy Cygnus A is hosted by the central galaxy of a cool core cluster, providing an ideal environment to observe its interactions with the surrounding intracluster medium (ICM) in the X-ray. In addition to the AGN, hotspots, cocoon shocks and shock compressed gas seen in deep Chandra observations, diffuse X-ray emission, primarily Compton scattered radio synchrotron emission, is also detected from the radio lobes. A circular hole with a radius of ∼3 kpc surrounding the primary hotspot is seen in the X-ray image of the eastern radio lobe. The depth of this feature is significantly greater than its diameter, indicating that it has been carved by the outgoing jet on its way to the larger and brighter secondary hostspot, after deflecting off the ICM at the primary hotspot. The absence of a corresponding feature in the west is likely a consequence of Doppler beaming. Some implications of these findings will be discussed.

106.22 — Constraining the power of X-ray winds: a Bayesian approach

Anna Ogorzalek[1,2]; Ashley King[1,2]; Steven Allen[1,2]; Jon Miller[3]; Daniel Wilkins[1,2]; John Raymond[4,5]; Adam Mantz[1,2]

[1] *Stanford University (Stanford, California, United States)*

[2] *KIPAC (Stanford, California, United States)*

[3] *University of Michigan (Ann Arbor, Michigan, United States)*

[4] *Harvard University (Cambridge, Massachusetts, United States)*

[5] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

A key outstanding question in our understanding of AGN feedback is the physics of accretion-driven black hole outflows, which may be powerful enough to prevent the stars from forming. However, without precisely mapping the ionization, velocity, and, crucially, density structure of these highly ionized winds, we cannot constrain their impact on the host galaxy evolution. In this talk, I will introduce our improved Bayesian framework to characterizing X-ray detected AGN outflows, wherein the ionizing spectrum and wind absorption are treated self-consistently within an MCMC analysis. This provides substantial improvements in our ability to explore parameter space and to recover the covariance between the emission and absorption parameters. For the first time we are able to perform robust model selection, which allows us to discriminate between non-nested models and establish how many wind components are required by the data. We have successfully applied this approach to one of the deepest Chandra HETG observations of an AGN, a new 700 ks observation of NGC 4051. Within our framework we were able to select the most reliable continuum model, in particular the soft excess emission, and discriminate between the wind and hot Milky Way ISM absorption features present in high resolution spectra. This approach also utilizes density- sensitive line transitions (here, the Fe XXII doublet), enabling us to obtain one of the tightest wind density measurements to date. As a result, we could precisely constrain the location and kinetic power of the outflow in NGC 4051. Our future work will extend the analysis to a population study of the physical structure and duty cycles of disk winds in local AGN, and serve as a pathfinder for the upcoming high spectral resolution X-ray missions, including XRISM, Arcus, and ATHENA.

106.23 — The Polarization Behaviour Of Blazars

Abel Lawrence Peirson[1]; Roger Romani[1]

[1] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University (Stanford, California, United States)*

The polarization fraction and electric vector position angle (EVPA) of blazar emission have long been known to exhibit stochastic variability, but recent monitoring campaigns have revealed new patterns in the polarization behavior. In particular RoboPol optical monitoring has identified episodes of relatively steady rotation of the EVPA, sometimes extending many turns; these can last weeks or months (Blinov et al. 2015) and can be (sometimes) associated with intensity flares (Blinov et al. 2016).

We describe a geometric model for synchrotron and inverse Compton radiation in blazar jets, involving multiple emission zones with turbulent magnetic fields and an intermittent core with a helical B-field. Including the effects of jet divergence, particle cooling, and relativistic position angle rotation to the observer frame, we recover polarization behavior similar to that observed in the optical monitoring and make predictions for correlated polarization in other wavebands.

We also identify some new patterns that may be present in the data. For example, relativistically- induced 'stepping' in EVPA rotation rates and modulation in polarization fraction may be observed and can constrain the jet bulk gamma and viewing angle. Also, higher polarization may be expected in the exponential tail of the synchrotron component. As expected, polarization of the inverse Compton component is generally low. The prospects for new tests of these ideas with IXPE X-ray polarization measurements are exciting and we develop simulations to predict and visualize the signal from bright blazar targets.

The work was supported in part by NASA grant NNM17AA26C

106.24 — Unraveling the Physics of Quasar Jets Using HST Polarimetry

Eric S. Perlman[1]; Devon Clautice[1]; Mihai Cara[2]; Sebastian Jester[3]; Klaus Meisenheimer[3]; Richard Perley[4]; Stefi Bau[5]; Mitchell Begelman[6]; John Biretta[2]; Mark

Birkinshaw[7]; Chi C. Cheung[8]; Paolo Coppi[9]; Jean Eilek[10]; Herman Marshall[11]; Andre Martel[12]; Christopher O'Dea[5]; Rita Sambruna[13]; William Sparks[2]; Lukasz Stawarz[14]; Yasunobu Uchiyama[15]; C. Meg Urry[9]; Diana Worrall[7]

[1] *Aerospace, Physics & Space Science Dept., Florida Institute of Technology (Melbourne, Florida, United States)*

[2] *New Mexico Institute of Mining & Technology (Socorro, New Mexico, United States)*

[3] *Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*

[4] *Johns Hopkins University (Baltimore, Maryland, United States)*

[5] *National Aeronautics & Space Administration (Washington, District of Columbia, United States)*

[6] *Jagiellonian University (Krakow, Poland)*

[7] *Tokyo (Japan, Japan)*

[8] *Space Telescope Science Institute (Baltimore, Maryland, United States)*

[9] *Max Planck Institut fur Astronomie (Heidelberg, Germany)*

[10] *National Radio Astronomy Observatory (Socorro, New Mexico, United States)*

[11] *University of Manitoba (Winnipeg, Manitoba, Canada)*

[12] *University of Colorado (Boulder, Colorado, United States)*

[13] *University of Bristol (Bristol, United Kingdom)*

[14] *Naval Research Laboratory (Washington, District of Columbia, United States)*

[15] *Yale University (New Haven, Connecticut, United States)*

Polarization is a critical parameter for understanding jet flows, as their radio to optical emission is produced by synchrotron radiation, which is naturally polarized, with the inferred magnetic field direction indicating the magnetic field direction in the emission region. Polarization has proven essential in characterizing the physics of FR I jets, where it has helped us map out their magnetic field and energetic structure and the relationship of this structure to the high-energy emission and particle acceleration. To date, high-quality HST polarimetry has been analyzed for just one FR II jet, that of PKS 1136-135. To rectify this, we have obtained new HST polarimetry observations of three key FR II jets – 3C 273, PKS 0637-752, and 1150+497. These new observations allow for the determination of the magnetic field structure and confirmation of which emission mechanisms are operating to create the observed optical to X-ray emission, and will allow us to greatly advance modeling efforts for these jets and nail down their kinetic power, a key parameter for understanding quasars and their cosmological effects.

106.25 — Relativistic reconnection in pair-proton plasmas and application to AGN jets

Maria Petropoulou[1]; Lorenzo Sironi[2]; Anatoly Spitkovsky[1]; Dimitrios Giannios[3,4]

[1] *Department of Astrophysical Sciences, Princeton University (Lawrenceville, New Jersey, United States)*

[2] *Columbia University (New York City, New York, United States)*

[3] *Purdue University (West Lafayette, Indiana, United States)*

[4] *University of Crete (Heraklion, Greece)*

Magnetic field dissipation via reconnection is a promising process for explaining the non-thermal signatures from a variety of relativistic astrophysical outflows, such as pulsar wind nebulae (PWNe) and jets of active galactic nuclei (AGN). In most relativistic astrophysical outflows reconnection proceeds in the so-called relativistic regime in which the Alfven velocity of the plasma approaches the speed of light. In contrast to PWNe, where the outflow is composed of relativistic pairs, in AGN jets the composition of the plasma is largely unknown. *Our goal is to study the general properties of relativistic reconnection in the unexplored regime of plasmas with mixed particle composition*. We focus on pair-proton plasmas, as they bridge the gap between the pair plasma and electron-proton plasma cases that have been extensively studied in the past. We perform a suite of 2D PIC simulations using the realistic proton-to-electron mass ratio (m_i/m_e=1836) while varying three physical parameters, namely the plasma magnetization, the plasma temperature, and the pair multiplicity. We study, for the first time, the energy distributions of accelerated particles, the inflows and outflows of plasma in the reconnection region, and the energy partition between pairs, protons, and magnetic fields, as a function of the pair multiplicity in the regime where protons dominate the rest mass energy of the plasma. We finally discuss our results in the context of non-thermal emission from AGN jets.

106.26 — Discovery of Two "X-ray-Only" Jets in a Survey of High Redshift Radio Quasars.

Daniel Schwartz[1]; Aneta Siemiginowska[1]; Diana Worrall[2]; Mark Birkinshaw[2]; Teddy Cheung[3]; Herman Marshall[4]; Guilia Migliori[5]; John Wardle[6]; Doug Gobeille[7]

[1] *High Energy Astrophysics Division, Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

[2] *HH Wills Physics Laboratory, University of Bristol, (Bristol, United Kingdom)*

[3] *Space Science Division, Naval Research Laboratory (Washington, District of Columbia, United States)*

[4] *Kavli Institute, MIT (Cambridge, Massachusetts, United States)*

[5] INAF Istituto di Radioastronomia (Bologna, Italy)
[6] Physics Department, Brandeis University (Waltham, Massachusetts, United States)
[7] Physics Department, University of Rhode Island (Kingston, Rhode Island, United States)

We have discovered two more cases of X-ray jets for which an underlying radio jet is not detected. Together with J0730+4049 at z=2.50, the first discovery of such a system by Simionescu et al. (2016), we claim that the existence of such a class of jets is established. These two quasars are a sub- set from the complete survey by Gobeille et al. (2014), selected by restricting the redshift to be z>3 and to have some extended radio emission. The detections are just above threshold and thus with uncertain properties; nonetheless, they are consistent with the surface brightness of J0730 (if their widths are similar), as expected from inverse Compton scattering of the cosmic microwave background.

106.27 — Proper Motions of the X-ray Knots in M87

Bradford Snios[1]; Paul E. J. Nulsen[1]; Ralph P. Kraft[1]; Eileen Meyer[2]; Chi C. Cheung[3]; William R. Forman[1]; Christine Jones[1]; Stephen S. Murray[1]
[1] Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)
[2] University of Maryland Baltimore County (Baltimore, Maryland, United States)
[3] Naval Research Laboratory (Washington, District of Columbia, United States)

We report results from *Chandra* HRC observations investigated for evidence of proper motions and brightness changes in the X-ray jet of M87. Using images spanning 5 years, proper motions from X-ray emission are detected for the first time in the system, with superluminal motions up to 6.3c observed along the X-ray jet axis. Proper motion estimates are found for the two knots closest to the AGN, HST-1 and Knot D, while upper limits are placed on the remaining jet features. Comparisons are performed between the X-ray results and previous measurements from other energy bands, and excellent agreement is observed both in spatial positions and proper motion speeds. Brightness variations up to 53% are found for the X-ray knots. By modeling the knots, synchrotron cooling is found to be the most probable source of the observed fading. Using the synchrotron cooling models, lower limits on magnetic field strengths of 700 μG and 150 μG were found for Knots HST-1 and A, respectively.

106.28 — An Extreme Ultrafast Outflow in the Seyfert 2 Galaxy IRAS 00521-7054

Dominic James Walton[1]; Emanuele Nardini[2]; Luigi Gallo[3]; Mark Reynolds[4]; Claudio Ricci[5]; Thomas Dauser[6]; Andrew Fabian[1]; Javier A. García[7]; Fiona Harrison[7]; Guido Risaliti[8]; Daniel Stern[9]
[1] Institute of Astronomy, University of Cambridge (Cambridge, Cambridgeshire, United Kingdom)
[2] Osservatorio Astrofisico di Arcetri (Florence, Italy)
[3] Saint Mary's University (Halifax, Nova Scotia, Canada)
[4] University of Michigan (Ann Arbor, Michigan, United States)
[5] Universidad Diego Portales (Santiago, Chile)
[6] Dr. Karl Remeis-Observatory (Bamberg, Germany)
[7] California Institute of Technology (Pasadena, California, United States)
[8] University of Florence (Florence, Italy)
[9] Jet Propulsion Laboratory (Pasadena, California, United States)

I will present results from a deep observation of the Seyfert 2 galaxy IRAS 00521-7054 with XMM-Newton (175 ks) and NuSTAR (400 ks). This observation caught the source in an unusually low-flux state, a factor of ∼6 fainter than the available data in the archive. Our broadband coverage allows us to disentangle the absorption and reflection in this highly complex source, and we find a strong contribution from relativistic reflection from the inner accretion disk, implying the presence of a rapidly rotating black hole. We also find strong statistical evidence for absorption in an 'ultrafast' outflow, with a truly extreme outflow velocity of ∼0.4c. Extensive simulations find the outflow to be detected in excess of 4-sigma significance. This is the second-fastest wind seen in absorption in any AGN to date. Under reasonable assumptions, we estimate that the outflow likely carries sufficient energy to drive significant galaxy-scale AGN feedback, and may even dominate the energy output from the system.

106.29 — High energy emission from pair-producing gaps at the base of AGN jets

Yajie Yuan[1]; Alexander Yuran Chen[1]; Huan Yang[2,3]
[1] Department of Astrophysical Sciences, Princeton University (Princeton, New Jersey, United States)
[2] Perimeter Institute for Theoretical Physics (Waterloo, Ontario, Canada)
[3] University of Guelph (Guelph, Ontario, Canada)

Some active galactic nuclei (AGN), including non-Blazars, show rapid gamma- ray variability that might originate from very close to the black hole. Particularly in low-luminosity AGNs, it is believed that a local region with unscreened electric field could develop in the black hole magnetosphere, accelerating particles to produce high energy gamma-rays, which in turn create $e^{\pm}$ pairs. We carry out time-dependent self-consistent 1D PIC simulations of this process, including inverse Compton scattering and photon tracking. We find a highly time-dependent solution where a macroscopic gap opens quasi-periodically to create $e^{\pm}$ pairs and high energy radiation. If this gap is operating at the base of the jet in M87, we expect an intermittency on the order of a few r_g/c, which coincides with the time scale of the observed TeV flares from the same object. We also discuss other potential observational implications, e.g., synchrotron emission from secondary pairs produced in the gap that might contribute to the X-ray spectrum.

106.30 — Probing a X-ray signature of multiple recollimation shocks in the blazar Mrk 421

Olivier Hervet[1]

[1] *University of California, Santa Cruz (Santa Cruz, California, United States)*

Mrk 421, as most of the TeV high-frequency-peaked BL Lacs (HBLs), show stationary or slow motions of its VLBI radio-knots structure, in stark contrast with its known fast variability. This problem, known as "the bulk Lorentz factor crisis", can be resolved if we consider that these strings of knots are successive recollimation shocks in jets. Successive shocks predict that a unique pattern of the non-thermal emission variability should appear after each strong flare. Using the 13 years long dataset of the NASA space telescope Swift-XRT, I present the detection of such a distinct pattern at more than 3 sigma of significance against stochastic fluctuations. Then I show how this pattern can be used as an innovative way to unveil the physical properties of the Mrk 421 jet, such as the flow apparent speed, the size of jet perturbations, and the jet beaming parameters.

106.31 — A QPO in NGC 4945 from Archival RXTE Data

Evan Smith[1]*; Eric S. Perlman*[1]*; Rebecca Robles*[1]

[1] *Florida Institute of Technology (Melbourne, Florida, United States)*

Quasi-periodic oscillations (QPOs) are an important observable in accretion disk. QPOs have been studied extensively in both neutron star and black hole x-ray binaries (BHXRB), and should be present in Active Galactic Nuclei (AGN) if galactic black holes and supermassive black holes (SMBH) are governed by a common set of physical processes. The search for QPOs in AGN has proven difficult because the timescales would be much longer, due to their higher mass. Some candidate QPOs remain unconfirmed, but two reasonably strong cases have been found, a 0.27-mHz QPO (period = 3733 ± 140 s) in REJ 1034+396, which has been compared with the 67-Hz QPO in the BHXRB GRS1915+105, and a 0.15-mHz QPO (~2-hr) in MS 2254.9–3712.

To look for low-frequency QPOs, we have investigated archival data from the *Rossi X-ray Timing Explorer* (RXTE) satellite collected between 1996 and 2011. AGN monitoring on a regular cadence was performed for many sources, and reduced light curves have been prepared and archived (Rivers et al., 2013). A total of 533 RXTE observations were made of the Seyfert-2 AGN, NGC 4945. During a large cluster of observations in 2006-2007 (194 observations spanning 396 days), the Lomb-Scargle periodogram shows a candidate QPO at 27.4 μHz (period = 42.3 days). A folded light curve on this period shows a relatively smooth variation. We also investigate SWIFT BAT data for this source covering the same time period.

106.32 — Resolving the AGN Torus Spectrally, Spatially, and Temporally

Mislav Balokovic[1]

[1] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

NuSTAR observations of obscured AGN in the local universe enable basic structural parameters of the obscuring torus, such as the covering factor and the globally averaged column density, to be observationally constrained from the X-ray band. We have recently completed an analysis of these parameters in a large sample of 140 obscured AGN selected from the Swift/BAT catalog and observed simultaneously with NuSTAR and Swift. However, detailed analyses of particular AGN reveal that parameters of simple torus models may depend on the choice of the fitting model and its nuisance parameters, variability in intrinsic luminosity or line-of-sight column density, and contamination from non-nuclear emission. In modeling spatially unresolved single-epoch AGN spectra, these effects can be sources of systematic uncertainties that exceed statistical uncertainties on important structural parameters of the accretion flow. Using novel spectral models and archival data for nearby AGN, I will demonstrate how broadband X-ray spectroscopy (0.5-200 keV) can be self- consistently combined with spatially resolved and multi-epoch X-ray data in order to obtain more robust constraints. Together with the future ability to probe velocity structures with high-resolution X-ray data, this will help us to better understand the complex AGN structure widely known under the deceptively simple name of the torus.

106.33 — Comparison of disk and broad line region sizes in the AGN NGC 4593

Edward Cackett[1]

[1] *Department of Physics & Astronomy, Wayne State University (Detroit, Michigan, United States)*

The active galactic nucleus, NGC 4593, was monitored daily with the Hubble Space Telescope during a ~month long period in July - August 2016. During each observation spectra from the UV through near-IR were obtained. Combining with high-cadence Swift photometric monitoring we measure significant reverberation lags for eight broad emission lines. The lags broadly scale with line width, as expected for virialized motion and give a black hole mass estimate consistent with previous values. Generally, the lags for the most highly ionized lines are shorter than the continuum reverberation lags measured from the same campaign. If the continuum reverberation lags are dominated by reprocessing in the accretion disk, this implies the broad line region is well within the extent of the optical-emitting accretion disk.

106.34 — The detection of ionized reflection in the super-Eddington Broad Line Radio Galaxy 3C109.

Sulov Chalise[1]*; Anne Lohfink*[1]*; Laura Brenneman*[2]*; Erin Kara*[4]*; Helen Russell*[3]

[1] *Department of Physics, Montana State University-Bozeman (Bozeman, Montana, United States)*

[2] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

[3] *University of Cambridge (Cambridge, United Kingdom)*

[4] *University of Maryland (College Park, Maryland, United States)*

Relativistic Active Galactic Nuclei (AGN) jets, whose formation is poorly understood, have a significant impact on the evolution of their host galaxies. BLRGs, the radio-loud analogues to Seyfert 1 galaxies, are excellent sources to study the AGN jet-forming region, as they are neither totally obscured nor overpowered by the jet. We present recent high-quality X-ray (NuSTAR and XMM- Newton), optical/UV (XMM-OM) and radio (AMI) observations of 3C109 (z = 0.3056), which is one of the most luminous BLRGs. We find that 3C109 possesses long-term variability but no significant short-term variability in the X-ray band. Using the X-ray reflection spectrum along with the optical/UV data, we can put stringent constraints on parameters like the high-energy cutoff, reflection fraction and inner-disk radius. Radio data will quantify the jet strength. Our results will be placed into the wider context of what is known about the jet formation in BLRGs.

106.35 — Neutrinos from hadronic cascades: the case of the 2014-15 neutrino flare from TXS 0506+056

Maria Petropoulou[1]*; Kohta Murase*[2]*; Derek Brindley Fox*[2]*; Nobuyuki Kawai*[3]

[1] *Department of Astrophysical Sciences, Princeton University (Lawrenceville, New Jersey, United States)*

[2] *Penn State University (State College, Pennsylvania, United States)*

[3] *Tokyo Institute of Technology (Tokyo, Japan)*

Gamma-ray flares from blazars have been suggested as ideal periods for the detection of high-energy neutrinos. Indeed, the first ~3σ high-energy neutrino source association was based on the detection of a single neutrino (IC-170922) coincident with the flaring blazar TXS 0506+056. A follow-up analysis of IceCube archival data revealed a past "neutrino flare" (13 ± 5 events within ~ 6 months) from the direction of TXS 0506+056 which, however, was not accompanied by any electromagnetic flare. Here, we investigate whether leptohadronic models of blazar emission can explain the 2014-15 neutrino flare without violating existing electromagnetic observations. To do so, we perform a wide scan of the available parameter space and numerically compute the neutrino and electromagnetic emission of the hadronic cascade for ~ 50 parameter sets. We explore both synchrotron-supported and Compton-supported electromagnetic cascades in the linear and non-linear regimes. We compare our model predictions against publicly available data from IceCube and Fermi-LAT and the X-ray upper limits we derived by analyzing archival BAT and MAXI data. We find no model that can simultaneously explain the neutrino flare and satisfy all electromagnetic constraints, thus implying the presence of more than one emitting regions in TXS 0506+056.

106.36 — Quantifying the rate of dual-AGN with BAYMAX

Adi Foord[1]*; Kayhan Gultekin*[1]*; Mark Reynolds*[1]*; Edmund Hodges-Kluck*[2]

[1] *Department of Astrophysics, University of Michigan (Ann Arbor, Michigan, United States)*

[2] *NASA GSFC (Greenbelt, Maryland, United States)*

We present BAYMAX (Bayesian AnalYsis of Multiple AGN in X-rays), a tool that uses a Bayesian framework to quantitatively evaluate whether a given *Chandra* observation is a more likely a single or dual point source. Although the most robust method of determining the presence of dual AGNs is to use X-ray observations, only sources that are widely separated relative to the instrument PSF are easy to identify. It becomes increasingly difficult to distinguish dual AGNs from single AGNs when the separation is on the order of *Chandra*'s angular resolution (<1"), as we primarily rely on visual interpretation to determine their nature. Using likelihood models for single and dual point sources, BAYMAX is able to quantitatively evaluate the likelihood of a dual AGN for a given source via a Bayesian analysis. Specifically, we present results from BAYMAX analyzing the lowest-mass dual AGN candidate to date, SDSS J091449.05, where archival *Chandra* data shows a possible secondary AGN 0.3" from the primary. Analyzing a new 50 ks *Chandra* observation, results from BAYMAX show that SDSS J091449.05 is most likely a single-AGN based on detailed comparisons of our models to the data. Further, posterior distributions from the dual point source model are consistent with emission from a single AGN. Overall, BAYMAX will be an important tool for correctly classifying candidate dual AGNs in the literature, and, for first time, study the dual AGN population where past spatial resolution limits have prevented systematic analyses.

106.37 — Confronting Comptonization and Reflection Models to Explain the Soft-Excess in AGN : The Case of Mrk 509

Javier A. García[1,2]
[1] *California Institute of Technology (Arcadia, California, United States)*
[2] *Dr Karl-Remeis Observatory (Bamberg, Germany)*

The observed X-ray spectra from active galactic nuclei (AGN) in Seyfert (Sy) galaxies is typically dominated by a power-law continuum with a flat distribution in energy density extending to high energies. In a large fraction of these sources (as high as 50%), a strong and featureless component is observed in excess to this continuum, peaking at soft energies at ~1–2 keV. The origin of this soft-excess has been matter of debate for the last three decades. Presently, the two leading explanations are: (1) the presence of an optically thick (τ~10—20) and warm corona (kT~0.5 keV) that Comptonizes disk photons; or (2) reprocessing of the power-law photons into a very dense inner accretion disk which produces a reflection spectrum smeared by relativistic effects near the black hole. We present a spectral analysis of recent NuSTAR and Suzaku observations of the Sy 1 AGN Mrk 509 implementing both of these models to describe the broad band X-ray spectrum. These two scenarios yield equivalent fit statistics. However, through detailed photoionization calculations, we show that even in the most favorable conditions the warm corona will also produce very strong absorption features4 which are inconsistent with the observed data. Meanwhile, the relativistic reflection scenario requires both extreme blurring and high density, a configuration favored by enhancement of X-ray flux at soft energies due to the additional free-free heating in a dense reflector. Therefore, based on our analysis, we favor the high-density relativistic reflection scenario (2) to explain the soft excess in Mrk 509. We further discuss the implications of these new high density models in mitigating the very large iron abundances typically derived from reflection spectroscopy studies.

106.38 — Warm Absorber Diagnostics of AGN Dynamics

Timothy Kallman[1]; *Anton Dorodnitsyn*[1]
[1] *NASA/GSFC (Greenbelt, Maryland, United States)*

Warm absorbers and related phenomena are one of the observable manifestations of outflows or winds from active galactic nuclei (AGN). Warm absorbers include a rich array of line and continuum absorption and emission. They are common in low luminosity AGN and can be fitted by simple phenomenological models. Major open questions remain: What is the driving mechanism? What is the density and geometrical distribution? How much associated fully ionized gas is there? In this paper we present synthetic spectra for the observable properties of warm absorber flows and associated quantities. We start with ab initio dynamical models, i.e. solutions of the equations of motion for gas in three dimensions using the Athena MHD code. Initial conditions consist of a torus at approximately 1 pc from a supermassive black hole. The models explore physical mechanisms affecting motion of the warm absorber gas, i.e. gas pressure due to X-ray heating, radiation pressure, and MHD forces. We calculate synthetic spectra by solving the formal solution to the radiation transport equation, including the effects of heating and ionization by X-rays emitted close to the central black hole. We discuss the systematic behavior of the model results including direct comparison with observed AGN spectra. We discuss the comparison for various scenarios for warm absorber dynamics.

106.39 — The broadband X-ray spectrum of the X-ray obscured Type 1 AGN 2MASX J19301380+3410495

Nikita Kamraj[1]; Mislav Balokovic[2]; Fiona Harrison[1]; Murray Brightman[1]; Dom Walton[3]

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

[2] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

[3] *University of Cambridge (Cambridge, Cambridgeshire, United Kingdom)*

We present results from modeling the broadband X-ray spectrum of the Seyfert 1.5 galaxy 2MASX J19301380+3410495 using NuSTAR, Swift/XRT and archival XMM-Newton observations. We find this source to be highly obscured, with column densities exceeding 10^{23} cm^{-2}across all epochs, yet it consistently exhibits prominent broad optical emission lines. We fit the X-ray spectra with both phenomenological reflection models and physically-motivated torus models, and find that the source exhibits a moderate Compton hump with a fairly weak Fe Kα line (EW ~ 82 eV). We also find the source possesses a coronal temperature that is atypically low compared to the local Seyfert population (kT ~ 37 keV). We discuss possible scenarios to explain mismatches between optical and X-ray classifications and the implications of low coronal temperatures on the heating and thermalization mechanisms in the corona.

106.40 — Probing the active galactic nuclei (AGN) torus structure using X-ray spectral variability.

Sibasish Laha[1]; Alex Markowitz[1]; Robert Nikutta[2]; Richard E. Rothschild[1]; Mirko Krumpe[3]

[1] *Centre for Astronomy and Space science, University of California, San Diego (San Diego, California, United States)*

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

[3] *Leibniz institute for astrophysics (Potsdam, Germany)*

It is still a big puzzle as to how the host galaxy gas (at kpc scales) feeds the accretion disk of a supermassive black hole (SMBH), at sub-pc scales, and thereby fuels the central engines of active galactic nuclei (AGN). Circumnuclear structures such as the cold, dusty "torus" are believed to be an active step in SMBH accretion, but the nature and structure of the torus in AGN is still highly debated, with various theoretical models encompassing continuous or clumpy distributions. A further complication is potential absorption from host galaxy structures. A major probe of morphology and location of line of sight gas is the variable absorption detected in the 0.3-10 keV X-ray spectra. Here, we present the latest results from an extensive X-ray spectral variability study of a sample of 20 perpetually- absorbed Compton-thin type IIs using XMM, Chandra, Suzaku and NuSTAR. In some objects, namely most low-N_H targets, our findings support the notion that X-ray absorption is not necessarily indicative of a compact, pc-scale torus; host galaxy structures at kpc scales likely contribute. In other objects, the high and non-variable value of N_H suggests a mostly smooth, continuous torus. We add to the evidence of clumpy structures at « pc scales: we note partial-covering structures sustained across nearly half the sample. In addition, we find evidence for clumpy or inhomogeneous full-covering compact structures in five additional sources. In conclusion, we cannot assign a common source of X-ray absorption across the sample. We thus urge caution in drawing conclusions about the properties of the compact torus without properly accounting for the absorption contribution from the host galaxy.

106.41 — *NuSTAR* Unveils an Extremely Local Compton-thick AGN in NGC 4968

Stephanie LaMassa[1]; Tahir Yaqoob[2,3]; Peter Boorman[4]; Poshak Gandhi[4]; Tim Heckman[5]; Nancy Levenson[1]; Andrew Ptak[2]; Jane Rigby[2]; Panayiotis Tzanavaris[2]; C. Meg Urry[6]

[1] *Space Telescope Science Institute (Baltimore, Maryland, United States)*

[2] *NASA GSFC (Greenbelt, Maryland, United States)*

[3] *UMBC (Baltimore, Maryland, United States)*

[4] *University of Southampton (Southampton, United Kingdom)*

[5] *The Johns Hopkins University (Baltimore, Maryland, United States)*

[6] *Yale University (New Haven, Connecticut, United States)*

The *Chandra* spectrum of NGC 4968, a local Seyfert 2 galaxy at D ~ 44 Mpc, revealed signatures of circumnuclear star formation and heavy obscuration (N_H > 10^{24} cm^{-2}), with a large Fe K alpha equivalent width of 2.5 keV. Such extreme iron fluorescence is rare, even for Compton-thick AGN, and suggested the AGN was buried in a spherical distribution of obscuring gas. We obtained follow-up *NuSTAR* spectra in 2017 and 2018 to characterize the > 10 keV spectrum, accurately measure the column density, and assess the geometry of the X-ray reprocessor. Using self- consistent, physically motivated X-ray spectral models, we rule out a spherical obscurer, in con-

trast to clues provided by the *Chandra* only spectrum. The models we use allow us to independently measure the line-of- sight and global column density. We find the line-of-sight column density to be Compton-thick, potentially exceeding 10^{25} cm^{-2}. Despite being very local and intrinsicially luminous in X-rays, *NuSTAR* is the only instrument that can currently resolve NGC 4968 above 10 keV.

106.42 — Exploring AGN Structure with Reflection and Reprocessing in Swift/BAT AGN

Lauranne Lanz[1]; Ryan Hickox[1]; Mislav Balokovic[2]; Taro Shimizu[3]; Claudio Ricci[4]; Andy Goulding[5]; David Ballantyne[6]; Franz E. Bauer[7]; Chien-Ting Chen[8]; Agnese del Moro[3]; Duncan Farrah[9]; Michael Koss[10]; Stephanie LaMassa[11]; Alberto Masini[1]; Luca Zappacosta[12]

[1] *Department of Physics and Astronomy, Dartmouth College (Hanover, New Hampshire, United States)*
[2] *Eureka Scientific Inc. (Oakland, California, United States)*
[3] *Space Telescope Science Institute (Baltimore, Maryland, United States)*
[4] *INAF - Osservatorio Astronomico di Roma (Rome, Italy)*
[5] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*
[6] *Max-Planck Institute for Extra-terrestrial Physics (Garshing, Germany)*
[7] *Universidad Diego Portales (Santiago, Chile)*
[8] *Princeton University (Princeton, New Jersey, United States)*
[9] *Georgia Institute of Technology (Atlanta, Georgia, United States)*
[10] *Pontificia Universidad Católica de Chile (Santiago, Chile)*
[11] *Marshall Space Flight Center (Huntsville, Alabama, United States)*
[12] *University of Hawaii at Manoa (Honolulu, Hawaii, United States)*

One of the open questions regarding the structure of active galactic nuclei (AGN) is the diversity and distribution of the covering fraction of their obscuring torus. This problem has typically been approached either using clumpy torus modeling of IR observations or using X-ray obscuration column depth distributions as a proxy. We investigated this question using the sample of 69 Swift/BAT AGN with hard X-ray spectra from NuSTAR and IR spectral energy distribution from Herschel and WISE. We find a correlation between hard X-ray reflection and the IR emission, suggesting both of these emissions are due to processing of the intrinsic emission from the corona and accretion disk by the same structure, often called the torus. As the amount of reprocessing is likely to be related to the fraction of the sky covered by the torus, we modeled the X-ray reflection and IR emission expected for a range of covering fraction distributions to find those yielding observables consistent with our data. We find that broad distributions centered around a covering factor of at least 40% match our observations best. I will discuss this new methodology for exploring the covering fraction distribution of Swift-BAT AGN and its implications for the torus structure.

106.43 — Revealing Intermediate Disk Radii in NGC 4151 with Chandra

Jon Miller[1]; Edward Cackett[3]; Abderahmen Zoghbi[1]; Didier Barret[4]; Ehud Behar[5]; Laura Brenneman[2]; Andrew Fabian[6]; Jelle Kaastra[7]; Anne Lohfink[8]; Richard Mushotzky[9]; Kirpal Nandra[10]; John Raymond[11]

[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*
[2] *MPE (Garching, Germany)*
[3] *Harvard-Smithsonian CfA (Cambridge, Massachusetts, United States)*
[4] *Harvard-Smithsonian CfA (Cambridge, Massachusetts, United States)*
[5] *Wayne State University (Detroit, Michigan, United States)*
[6] *IRAP/OMP (Toulouse, France)*
[7] *Technion (Haifa, Israel)*
[8] *University of Cambridge (Cambridge, United Kingdom)*
[9] *SRON (Utrecht, Netherlands)*
[10] *Montana State University (Bozeman, Montana, United States)*
[11] *University of Maryland (College Park, Maryland, United States)*

Chandra HETG spectra of the nearby Seyfert AGN NGC 4151 reveal asymmetry in the profile of the narrow, neutral Fe K emission line. Numerous fits with both simple line models, and physical models including weak relativistic effects and scattering, strongly suggest that the line originates at radii less than R ~ 500-1000 GM/c^2. There is evidence that the line is broader when the flux is higher, potentially originating just R ~ 50-100 GM/c^2 from the black hole in high flux states. This differs from the relationship expected based on photoionization, although the latter is strongly confirmed in optical broad line variability studies. We discuss our findings in the context of geometric structures in the inner and intermediate disk and the nature and origin of the broad line region in Seyferts, and note that narrow Fe K line reverberation may be used to measure black hole masses using XRISM and Athena.

106.44 — The Analogous Structure of Accretion Flows in Supermassive and Stellar Mass Black Holes

John J. Ruan[1]; Scott F. Anderson[2]; Michael Eracleous[3]; Paul J. Green[4]; Daryl Haggard[1]; Chelsea Macleod[4];

Jessie C. Runnoe[5]; Malgosia Sobolewska[4]
[1] *Department of Physics, McGill University (Montreal, Quebec, Canada)*
[2] *University of Washington (Seattle, Washington, United States)*
[3] *Penn State University (State College, Pennsylvania, United States)*
[4] *Harvard Smithsonian CfA (Cambridge, Massachusetts, United States)*
[5] *University of Michigan (Ann Arbor, Michigan, United States)*

Over the past 20 years, several lines of evidence have suggested a connection between the structure of black hole accretion flows in active galactic nuclei (AGN) and Galactic X-ray binaries, despite their factor of $\sim 10^8$ difference in black hole mass. In particular, both the fundamental plane of black hole accretion and X-ray variability properties now suggest some link between the low-luminosity/hard-spectrum accretion state of X-ray binaries and low-luminosity AGN. However, it is still unclear whether the exact structure and geometry of the disk-corona system in X-ray binaries directly scale up in mass to AGN, and whether this analogy still holds when the accretion flow switches between different accretion states. I will present a novel approach to testing the X-ray binary/AGN connection, based on direct comparisons of faded 'changing-look quasars' to X-ray binary outbursts. Using Chandra X-ray and ground-based rest-UV observations of faded changing-look quasars, we probe the evolving geometry of their accretion flows as a function of Eddington ratio, based on the observed spectral changes. We find that the observed spectral evolution in fading quasars displays a remarkable similarity to accretion state transitions in X-ray binary outbursts. Our results show that the structures of black hole accretion flows directly scales across a factor of 10^8 in black hole mass and across different accretion states, thus enabling us to securely apply theoretical models of X-ray binaries to explain AGN phenomenology.

106.45 — Gamma-Ray Emission from Blazars: the Moving Mirror Model

Marco Tavani[1]
[1] *INAF and University of Rome Tor Vergata (Roma, Italy/Rm, Italy)*

Blazars emit gamma-rays above 100 MeV in a variety of modes related with jet acceleration properties and transport. Here we focus on the puzzling phenomenon of "orphan gamma-ray emission", that is enhanced gamma-ray transient radiation that does not correspond to optical/X-ray simultaneous emission. Notable examples include recent activity of 3C 454.3 and 3C 279 which showed gamma-ray-only flares with notable timing properties. We explain this phenomenon with a "moving mirror model" based on the radiative interplay of blobs ejected along the jet moving with different speeds. The space between approaching blobs can be filled with reflected radiation from the moving forward blob, and provide a very interesting condition for enhanced inverse Compton radiation. This latter radiation in the gamma-ray energy range is not directly associated with lower energy synchrotron emission in the optical or X-ray band, and it can occur at relatively large distance from the central source, possibly beyond the broad line region in the case of FSRQs. Decoupling IC and synchrotron radiation can explain the orphan gamma-ray emission of blazars, and also be useful in understanding the interplay of accelerated particles and a radiation environment providing target soft photons at large distance from the central source. Possible applications, in addition to FSRQs, extend to BL Lacs and neutrino blazar sources.

106.46 — Heating of the compact X-ray corona in Seyfert Galaxies

Yajie Yuan[1]; Anatoly Spitkovsky[1]; Roger Blandford[2]; Daniel Wilkins[2]
[1] *Department of Astrophysical Sciences, Princeton University (Princeton, New Jersey, United States)*
[2] *Stanford University (Stanford, California, United States)*

There is observational evidence that the X-ray continuum source that creates the broad fluorescent emission lines in some Seyfert Galaxies may be compact and located at a few gravitational radii above the black hole. We consider the possibility that the compact X-ray emitting source may be powered by small scale flux tubes near the black hole that are attached to the orbiting accretion disk. Using three dimensional, time dependent force-free simulations, we find that the field linking the black hole and the disk can get twisted up by the differential rotation to try to form a magnetic tower. When the confinement provided by the field from the outer disk is strong, the forming magnetic tower can quickly become kink unstable, which leads to continuous reconnection and dissipates most of the extracted rotational energy relatively close to the black hole. Such a process may be able to heat up the plasma and produce strong X-ray emission. We estimate the energy dissipation rate and discuss its astrophysical implications.

106.47 — The CATS survey: Radio and X-ray AGN evolution in Galaxy Clusters up to z∼1.5

Rebecca Canning[1]; Ashley King[1]; Emil Noordeh[1]
[1] *Stanford University (Stanford, California, United States)*

A critical prerequisite for both AGN activity, and the formation of new stars in host galaxies, is the availability of gas. Environmental processes in dense environments affect gas reservoirs in ways that are different to the field. The density of cluster members and their relative velocities also depend on the cluster mass. As such, the rates of violent processes will differ in clusters and the field. The relative importance of these processes depends on both the position within, and the mass of, the host galaxy cluster.

The Cluster AGN Topography Survey (CATS) is mapping AGN across the electro-magnetic spectrum and determining how their properties depend on their surrounding LSS environments. Targeting ∼500 of the most massive galaxy clusters and generating a catalogue of ∼40,000 AGN, CATS exceeds previous studies of AGN in massive galaxy cluster environments by an order of magnitude. In this talk I will present the first full results of the X-ray AGN and Radio AGN cluster population evolution in massive galaxy clusters up to z∼1.5.

106.48 — AGN obscuration, Eddington ratio distributions, and clustering: Deep and wide X-ray surveys with *NuSTAR* and *Chandra* in the UKIDSS-UDS and Boötes fields

Ryan C. Hickox[1]; Alberto Masini[1]
[1] *Department of Physics and Astronomy, Dartmouth College (Hanover, New Hampshire, United States)*

X-ray surveys represent one of the most efficient methods to detect active galactic nuclei (AGN) and perform statistically powerful population studies. In the past decade, important results on AGN evolution have came from both wide and deep X-ray surveys of the sky performed by *Chandra* and *XMM- Newton*. The launch of *NuSTAR* in 2012 allowed to extend such sensitive surveys to higher energies, starting a fruitful synergy between hard and soft X-rays. On one hand, recent deep hard X-ray surveys confirmed the presence of a population of heavily obscured AGN: We will begin by present the results of a deep *NuSTAR* survey of the UKIDSS-UDS field, as well as the aggregated results in the COSMOS, ECDFS and UDS fields obtained exploiting three new hard *NuSTAR* bands. We will highlight an interesting source in the COSMOS field that is barely detected by *Chandra* due to heavy obscuration, but clearly stands out in the *NuSTAR* 8-16 keV band. We will then present the present status and future perspectives of the new *Chandra* survey in the central 6 deg^2 of the Bootes field (the *Chandra* Deep Wide Field Survey, CDWFS). The CDWFS X-ray catalog contains more than 7,500 sources when combining three *Chandra* bands. We will give an overview of future studies of the large-scale clustering of AGN and their Eddington-ratio distribution that will benefit from the exquisite *Chandra* angular resolution and sensitivity on this very large multiwavelength field. This work is supported in part by NASA grant NNX15AP24G and *Chandra* grant GO7-18130X.

106.49 — Chandra survey of optically selected AGN pairs

Meicun Hou[1]; Zhiyuan Li[1]; Xin Liu[2]
[1] *Nanjing University (Nanjing, China)*
[2] *University of Illinois at Urbana-Champaign (Urbana-Champaign, Illinois, United States)*

Active galactic nucleus (AGN) pairs are an ideal laboratory to study the effects of galaxy merger in the standard paradigm of galaxy formation and evolution. We present a Chandra archival survey of AGN pairsat median redshift ∼0.1, which were systematically identified from the Sloan Digital Sky Survey with projected separations rp < 100 kpc and velocity offsets <600 km s^{-1}. Out of the 1286 AGN pairs, we find 64 pairs with Chandra observations, making it currently the largest sample of AGN pairs studied in the X-ray band. The X-ray incidence rate, 67/128=52%±6%, is significantly higher than that (23/178=13%±3%) of a control sample of galaxy pairs which do not exhibit optical AGNs in their center, lending support to the optical AGN selection. The X-ray luminosity increases with decreasing projected separation in AGN pairs for rp > 10 kpc, suggesting an enhancement of central BH activity, while it decreases when rp < 10 kpc, which may be caused by obscuring, merger-induced gas inflows or gas depletion in the central region of AGNs.

106.50 — First results from the *NuSTAR* Obscured Seyferts Survey

Elias Kammoun[1]; Jon Miller[1]
[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

Current measurements show that the observed fraction of Compton-thick (CT) active galactic nuclei (AGN) is smaller than the expected values needed to reproduce the shape and brightness of the cosmic

X-ray background. It has proved difficult to study heavily obscured AGN in soft X-rays. This is due to the fact that for column densities approaching $\sim 10^{24}$ cm^{-2} the direct emission from the central engine can only be observed directly above ~15 keV. Thanks to its unprecedented sensitivity covering the 3 - 79 keV band, *NuSTAR* is playing a key role in identifying the missing fraction of these sources and determining their properties. In this talk, I will present the first results of the "*NuSTAR* Obscured Seyferts Survey" aiming to study an optically-selected volume- limited sample of 22 Seyfert-2 galaxies that were identified in the CfA Redshift Survey. This *NuSTAR* legacy survey will allow us to accurately measure the obscuring column densities, Eddington fractions and other fundamental properties of these sources. This would be accomplished by using physically motivated spectral models to fit the X-ray spectra of these obscured sources, which will additionally provide better insights on the geometry of the obscuring material. I will introduce the sample, describe the various spectral models employed in this work, and discuss the physical implications of our results. I will also discuss how future high-resolution X-ray observatories such as XRISM and Athena may improve our understanding of CT AGN in the soft X-rays.

106.51 — The BAT AGN Spectropic Survey (BASS) DR2: A Thousand New Spectra

Michael Koss[1]
[1] *Eureka Scientific (Kirkland, Washington, United States)*

The Burst Alert Telescope (BAT) instrument on the Swift satellite has surveyed the sky to unprecedented depth, increasing the all sky hard X-ray sensitivity by a factor of more than 20 compared to previous satellites. The goal of the BAT AGN Spectroscopic Survey (BASS) is to complete the first large (>1000) survey of hard X-ray selected AGN with optical spectroscopy. Here we present an overview of the second data release of spectra from Palomar/Doublespec and VLT/Xshooter and several other telescopes which includes redshift determination, absorption and emission line measurements, and black hole mass and accretion rate estimates via broad lines and velocity dispersion for over 1000 AGN.

106.52 — A Population of Luminous AGN with Hidden Galaxy Mergers

Michael Koss[1]*; Laura Blecha*[4]*; Richard Mushotzky*[3]*; Claudio Ricci*[2]*; Ezequiel Treister*[5]*; Benny Trakthenbrot*[6]
[1] *Eureka Scientific (Kirkland, Washington, United States)*
[2] *Universidad Diego Portales (Santiago, Chile)*
[3] *Department of Astronomy and Joint Space-Science Institute, University of Maryland (College Park, Maryland, United States)*
[4] *Department of Physics, University of Florida (Gainesville, Florida, United States)*
[5] *Instituto de Astrofísica, Facultad de Física, Pontificia Universidad Católica de Chile (Santiago, Chile)*
[6] *School of Physics and Astronomy, Tel Aviv University (Tel Aviv, Israel)*

Simulations suggest that the turbulent process of merging galaxies powers black hole growth. In the process of merging, as two galaxies spiral around each other, violent shocks disrupt the structure of the galaxies enabling gas to fall onto the black holes creating a dual AGN and also heavily obscuring them behind a screen of gas and dust. In the subsequent black hole merger, gravity waves are predicted which can result in a recoiling black hole that leaves the center of the galaxy. While the theoretical model is clear, recent observational studies have provided dramatically different scenarios and contradictory results. I will present new results using high resolution AO imaging and high energy X-rays that have enabled the detection of emission from these black holes even behind large amounts of obscuring gas and dust.

106.53 — A study of X-ray emission of galaxies hosting molecular outflows (MOX sample).

Sibasish Laha[1]*; Matteo Guainazzi*[2]*; Enrico Piconcelli*[3]*; Poshak Gandhi*[4]*; Claudio Ricci*[5]*; Ritesh Ghosh*[6]*; Alex Markowitz*[1]*; Joydeep Bagchi*[7]
[1] *Centre for Astronomy and Space science, University of California, San Diego (San Diego, California, United States)*
[2] *ESTEC (Noordwijk, Netherlands)*
[3] *Observatorio Astronomico di Roma (Rome, Italy)*
[4] *University of Southampton (Southampton, United Kingdom)*
[5] *Universidad Diego Portales (Santiago, Chile)*
[6] *Viswa Bharati University (Shantiniketan, India)*
[7] *IUCAA (Pune, India)*

The AGN feedback plays a crucial role in black hole and host galaxy coevolution across cosmic time. However, the exact nature of the interaction between AGN outflows and the host galaxy at kpc scales is not clearly understood. With the advent of high spatial resolution infra-red (IR) and radio telescopes in the past couple of decades, we have made rapid progress in detecting and understanding the nature of molecular outflows, which are outflows detected at kpc scales and mostly manifest themsleves in the IR/submm spectra as broadened emission and absorption lines. These molecular outflows may sometimes possess significant amount of kinetic and mass outflow rates, enough to impart feedback to the host galaxy gas and dust. Understanding the origin and driving mechanisms of these molecular outflows are therefore of paramount importance in order to decipher AGN and host galaxy interaction. We have carried out an extensive X-ray spectral analysis (Laha et al., ApJ 868:10, 2018) of a sample of 50 galaxies exhibiting molecular outflows (MOX sample) and characterized the X-ray properties of these galaxies to investigate the effect of the central AGN on their dynamical properties. We found two interesting results: 1. The AGN in the galaxies hosting molecular outflows (which are mostly infra-red bright ULIRGs and LIRGs) are not X-ray weak as were inferred using X-ray observations. Using the 12 micron AGN luminosity (from heated dust) as a proxy for the 2-10 keV AGN luminosity, we found that the central AGN are not X-ray weak and their hardness ratios are similar to that of the Seyferts. These galaxies are simply too obscured to be detected in X-rays, and in many cases obscured by Compton thick clouds. 2. The AGN plays a prominent role in driving the molecular outflows. However, we find that the starbursts are also influential in driving the molecular outflows. It still needs to be seen which one, AGN or starburst, plays the bigger role in driving these outflows.

106.54 — The Effect of Environment on the Evolution of Active Galactic Nuclei in the Dark Energy Survey

David Laubner[1]; Tesla Jeltema[1]
[1] *Department of Physics, UC Santa Cruz (Felton, California, United States)*

Although black hole growth and galaxy evolution are observed to be connected, it is difficult to determine why they co-evolve and how they affect each other. By studying the relationship between active galactic nuclei (AGN) and their environment, we can gain insight into this co-evolution. It is observed that galaxies in different environments evolve differently. For example, a galaxy in a heavily populated cluster may evolve differently from a galaxy in a relatively scarce field. In this study, I use overlapping archival Chandra X-ray data and the first three years of Dark Energy Survey data collection. In this presentation, I will discuss the relationship between AGN fraction and its environment including redshift and cluster richness. Preliminary results indicate a positive correlation between AGN fraction and redshift, and a relatively flat correlation between AGN fraction and cluster richness.

106.55 — A multi-observatory X-ray approach to characterize heavily obscured AGN

Stefano Marchesi[1]; Marco Ajello[1]; Xiurui Zhao[1]
[1] *Clemson University (Clemson, South Carolina, United States)*

According to the different models of Cosmic X-ray Background (CXB), the diffuse X-ray emission observed in the 1 to ~200-300 keV band, is mainly caused by accreting supermassive black holes, the so-called active Galactic Nuclei (AGN). Particularly, at the peak of the CXB (~30 keV) a significant fraction of emission (10-25%) is expected to be produced by a numerous population of heavily obscured, Compton thick (CT-) AGN, having intrinsic column density NH>=1E24 cm^{-2}. Nonetheless, in the nearby Universe (z<=0.1) the observed fraction of CT-AGN with respect to the total population appears to be lower than the one expected on the basis of the majority of CXB model predictions (~20-50%), being between 5 and 10%. This discrepancy between data and models is one of the open challenges for X-ray astronomers, and needs to be solved to get a complete understanding of the AGN population. In this presentation, I will discuss a multi-observatory X-ray approach to find and characterize heavily obscured AGNs. The starting point of the project is the 100-month Swift-BAT catalog, the result of a ~7 years all- sky survey in the 15-150 keV band and a powerful tool to select and identify nearby, heavily obscured AGNs.. These objects are then targeted with snapshot (5-10 ks) observations with Chandra and Swift-XRT, which allow us to constrain the intrinsic absorption value within a 20-30% uncertainty. Finally, deep (25-50 ks) observations with XMM-Newton and NuSTAR allow us to study the physics of these complex and elusive sources.

106.57 — Quasars as Standard Candles

Guido Risaliti[1]
[1] *University of Florence, Italy (Sesto Fiorentino, FI, Italy)*

The X-ray to UV non-linear relation in quasars can be used as a distance indicator, turning quasars into standard candles, We built a Hubble Diagram of quasars up to z~6, using about 2,000 sources with SDSS optical/UV spectra and XMM-Newton or Chandra X-ray spectra. We found that the expansion of the Universe traced by quasars perfectly match the results based on supernovae up to z~1,5, and is well reproduced by the concordance LCDM model. However, at higher redshifts a 4-sigma tension is found. If we allow for an evolution of the dark energy density, our data suggest an equation of state parameter w<-1.

106.58 — Possible Evidence of the Radio AGN Quenching of Neighboring Galaxies at z∼1

Lu Shen[1]

[1] *Department of Physics, University of California, Davis (Davis, California, United States)*

Using imaging from the Very Large Array at 1.4GHz, I have compiled a large sample of radio galaxies from the Observations of Redshift Evolution in Large Scale Environments (ORELSE) survey, a survey aimed at systematically searching for large-scale structures in the redshift range of $0.6 < z < 1.3$. By virtue of multi-wavelength imaging and high quality spectroscopy, as well as a wide dynamic range of envionments sampled by this survey, I classified radio galaxies to three types: AGN, Hybrid and Star Forming Galaxies, and further seperated them into different environments. In this talk, I will focus on the radio AGN, and, particularly, the possible effect of radio AGN on their neighboring galaxies. After carefully constructing and comparing to non-radio- detected control samples, a possible signature of additional quenching on radio AGN neighbors was found in high density cluster environments. I will discuss scenarios which may possibly explain this signature, including the possible heating of the intracluster medium due to radio AGN activity.

106.59 — Surveying the X-ray Properties of Candidate Subparsec SMBH Binaries

Daniel Stern[1]*; M. Lynnie Saade*[2]*; Murray Brightman*[3]*; Matthew J. Graham*[3]*; Dominic James Walton*[4]*; Zoltan Haiman*[5]*; Barry McKernan*[6]*; K. E.S. Ford*[6]

[1] *JPL/Caltech (Altadena, California, United States)*
[2] *UCLA (Los Angeles, California, United States)*
[3] *Caltech (Pasadena, California, United States)*
[4] *Cambridge (Cambridge, California, United States)*
[5] *Columbia (New York City, New York, United States)*
[6] *CUNY/AMNH (New York City, New York, United States)*

Graham et al. (2015) reported the discovery of 111 candidate optically periodic quasars out of an all-sky survey of 244,000 quasars. The most plausible mechanism for such periodicity involves supermassive black hole (SMBH) binaries with subparsec separations. Theoretical models for close SMBH binaries predict carved out regions of the circumbinary disk, mini-disks around the primary and secondary black holes, shock-heated accretion streams, and/or hot spots in the circumbinary disk. SMBH binaries can be much brighter in X-rays than single SMBHs of the same mass since the orbital energy of the binary is channeled into X-ray emission via shocks. We report on a Chandra Cycle 18 to test whether these periodic quasars are powered by a common mechanism, distinct from isolated quasars, from observations of six ROSAT- detected candidate periodic quasars.

106.60 — A deep look at nearby heavily obscured AGNs with NuSTAR and XMM-Newton

Xiurui Zhao[1]*; Stefano Marchesi*[1]*; Marco Ajello*[1]*; Lea Marcotulli*[1]*; Giancarlo Cusumano*[2]*; Valentina La Parola*[2]*; Christian Vignali*[3,4]

[1] *Clemson university (Clemson, South Carolina, United States)*
[2] *INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica (Palermo, Italy)*
[3] *INAF – Osservatorio Astronomico di Bologna (Bologna, Italy)*
[4] *Università di Bologna (Bologna, Italy)*

The cosmic X-ray background (CXB), the diffuse X-ray emission observed between 0.5 keV and 300 keV, is thought to be mainly produced by obscured and unobscured active galactic nuclei (AGN). Compton-thick (CT-) AGNs (with absorbing column density NH $>10^{24}$ cm^{-2}) are responsible for ∼30% of the CXB at its peak and expected to be numerous. However, as of today CT-AGNs have never been detected in large numbers, their observed fraction in the local universe being ∼5–10%, significantly below the predictions of different CXB models (∼20%–30%). I will present a deep observation of two candidate CT-AGNs, selected using an effective technique reported by our group two years ago, using the unprecedented-quality data from NuSTAR and XMM-Newton, which allows us to have a better understanding of the physics of the obscuration process in AGNs.

106.61 — Discovery of Reverberation of the Narrow Iron Fe K Line in AGN

Abderahmen Zoghbi[1]*; Jon Miller*[1]*; Edward Cackett*[2]*; Chris Reynolds*[3]*; Andrew Fabian*[3]

[1] *University of Michigan (Ann Arbor, Michigan, United States)*
[2] *Wayne State University (Detroit, Michigan, United States)*
[3] *University of Cambridge (Cambridge, United Kingdom)*

The narrow Fe K-alpha line is seen ubiquitously in AGN. It can be produced either the torus or in the X-ray Broad Line Region. Here, we present the results of X-ray spectral modeling of 22 observations of the brightest Seyfert nucleus in NGC 4151 with XMM-Newton. The observations probe variability timescales from more than a decade down to hours. We find the flux of the narrow Fe K-alpha to be strongly correlated with the continuum, providing a strong evidence for reprocessing. The data constrain the time delay to be less than ~5 days, which is shorter than the 6.6 days delay between the continuum and the H-beta line in the optical Broad Line Region (BLR). The shorter delay imply a smaller Fe K-alpha line emitting region. The delay and line width suggest that a geometry similar to the optical BLR cannot be ruled out. These results provide the first steps in narrow Fe reverberation mapping and black hole mass estimates. The data also suggests that the line width increases with flux, confirming recent similar results using Chandra observations. The relation suggests a varying viewing angle to the emission region, possibly due to an increasing scale height with radius or a warp.

106.62 — Evidence for a TDE origin of the radio transient Cygnus A-2

Martijn De Vries[1]; Michael Wise[1,2]; Paul E. J. Nulsen[3]; Aneta Siemiginowska[3]; Antonia Rowlinson[1,4]; Chris Reynolds[5]

[1] *University of Amsterdam (Amsterdam, Netherlands)*

[2] *Stichting Ruimteonderzoek Nederland (SRON) (Utrecht, Netherlands)*

[3] *Center for Astrophysics (Cambridge, Massachusetts, United States)*

[4] *Netherlands Institute for Radio Astronomy (ASTRON) (Dwingeloo, Netherlands)*

[5] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*

In 2015, a radio transient was discovered in Cygnus A with the VLA. This transient, named Cygnus A-2, is 0.42 arcsec removed from the AGN and can therefore not be spatially resolved by most X-ray telescopes. We have looked for an X-ray counterpart to Cygnus A-2, using Chandra ACIS observations from 2015 to 2017. We simulated the source with Marx and compared it with the data, and find no evidence of a secondary point source. Based on this, we put an upper limit to the 2-10 keV X-ray luminosity of Cygnus A-2 of 10^{43} erg/s.

We also present a spectral analysis of the AGN of Cygnus A using old and new Chandra observations. We compared the 2-10 keV X-ray luminosities with archival XMM-Newton, NuSTAR and Swift XRT data. The resulting light curve shows that the luminosity of Cygnus A was constant between 2000 and 2005, doubled in 2013 while observed by NuSTAR and Swift, and dropped back down in 2015. Previous analysis of the NuSTAR spectra has also indicated the presence of a fast, ionized wind, something not seen by Chandra and XMM-Newton in both earlier and later observations.

The above results have several implications for the nature of Cygnus A-2. If Cygnus A-2 is a steadily accreting black hole, the lack of detected X-ray emission implies that its mass is of order 10^8 $M_\odot$ or greater, using the Fundamental Plane for accreting black holes. At the same time, lack of any reported large-scale dynamical disturbances implies a mass significanty lower than that of the primary AGN of Cygnus A (2.5×10^9 $M_\odot$).

As an alternative option, we suggest that Cygnus A-2 is the radio afterglow of a tidal disruption event (TDE). The peak in X-ray luminosity seen by NuSTAR and Swift in 2013 could be explained as X-ray emission from this TDE, which would have faded by the time Cygnus A-2 was originally detected in 2015. Further support for this interpretation is the fact a couple of TDE's are able to launch short-lived, fast, ionized outflows, like the one that was detected in Cygnus A with NuSTAR. If Cygnus A-2 is indeed a TDE, it would provide further evidence that disruption rates in merging galaxies are higher than previously thought.

106.63 — Constraining spins of supermassive black holes when they tidally disrupt stars

Dheeraj Ranga Reddy Pasham[1]; Ronald Remillard[1]; Chris Fragile[3]; Alessia Franchini[2]; Nicholas Stone[5]; Giuseppe Lodato[4]; Jeroen Homan[6]; Deepto Chakrabarty[1]; Frederick Baganoff[1]; James F. Steiner[1]; Eric Coughlin[5]; Nishanth Pasham[7]

[1] *Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (MIT) (Cambridge, Massachusetts, United States)*

[2] *University of Las Vegas (Nevada, Nevada, United States)*

[3] *College of Charleston (Charleston, South Carolina, United States)*

[4] *Università degli Studi di Milano (Milan, Italy)*

[5] *Columbia University (New York, New York, United States)*

[6] *Eureka Scientific (Oakland, California, United States)*

[7] *Allyo (Santa Clara, California, United States)*

Supermassive black holes (SMBHs) exist at the centers of almost all massive galaxies. However, most of them are dormant and thus remain undetected. Nevertheless, roughly once every 10,000-100,000 years a star will pass close enough to the black hole such that the tidal forces will disrupt the star to produce a flare that can shine across the entire electromagnetic spectrum. As the shredded material falls on the black hole it emits X-rays when closest to the event horizon. Thus, studying the X-rays that originate from strong gravity regime in the immediate vicinity of the black hole and thus encode the information about the black hole's mass and spin. I will discuss our recent discovery of a persistent, high-amplitude 131-second X-ray modulation from a recent quintessential tidal disruption event. The periodicity is remarkably stable over 2.5 years or 600,000 cycles and its fractional root-mean-squared (RMS) modulation amplitude is unprecedented with a value over 40%. This is unlike any known black hole system. Using a black hole mass implied from host galaxy scaling relations and comparing this stable periodicity/frequency to the fundamental frequencies of motion predicted from general relativity, we find that the oscillation is too fast for this black hole, unless it is rapidly spinning (dimensionless spin parameter > 0.7). This discovery provides a new means to constrain spins of several massive black holes in future tidal disruption events. I will also discuss our efforts to discover similar signals in other tidal disruption flares using the soft X-ray missions including NICER and XMM-Newton in the coming years, and the prospects with STROBE-X and ATHENA in the next decade.

106.64 — Secular Evolution in the Nearest Tidal Disruption Event

Eric S. Perlman[1]; Eileen T. Meyer[2]; Qingde Daniel Wang[3]; Qiang Yuan[4]; Richard Henriksen[5]; Judith Irwin[5]; Jiangtao Li[6]; Haochuan Li[5]; Theresa Wiegert[5]

[1] *Aerospace, Physics & Space Science Dept., Florida Institute of Technology (Melbourne, Florida, United States)*

[2] *University of Maryland Baltimore County (Baltimore, Maryland, United States)*

[3] *University of Massachusetts (Amherst, Massachusetts, United States)*

[4] *Purple Mountain Observatory (Nanjing, Jiansu, China)*

[5] *Queens University (Kingston, Ontario, Canada)*

[6] *University of Michigan (Ann Arbor, Michigan, United States)*

Tidal disruption events (TDEs) occur when a star passes close enough to a galaxy's supermassive black hole to be disrupted by tidal forces. We discuss new observations of IGRJ12580+0134, a TDE observed in NGC 4845 (d=17Mpc), with the VLA, VLBA and ALMA. We also discuss a reanalysis of observations from 2010-2011 with Swift ad XMM-Newton, as well as late-time observations from those telescopes. IGRJ12580+0134's proximity offers us a unique close-up of the TDE and its aftermath. Our VLBA observations show a jetted milliarcsecond- scale nuclear source, while our *ALMA* observations show an unresolved, arcsecond-scale nuclear source. A source 45 milliarcsec from the nucleus that appeared in the 2015 L-band map is shown to be spurious. This map and our earlier data suggest a jet expansion velocity of $\sim$ 0.3 c between 2015-2017. This is consistent with the model of Perlman et al. (2017) and Irwin et al. (2015), which holds that while the jet started out moving at close to c, it decelerated to sub-relativistic speed within months due to interactions with the circumnuclear medium. They also show that while the decay of the GHz nuclear flux is consistent with the predictions of this model ($\propto t^{-5/3}$), the GHz spectral index α_r = 0.94 (which has remained constant since 2015) overpredicts the ALMA flux by a factor of three. We discuss the implications for TDE models, as well as models which suggest that a similarly dense nuclear medium could have a significant effect on the propagation of AGN jets. A reanalysis of the Swift and XMM-Newton data from 2011 January shows significant evidence for thermal emission from a disk. Later observations with Swift only detect the source when stacked. We use Fermi observations to set an upper limit on the GeV gamma-ray flux. We discuss the implications for both the nature of the source and its continued evolution, which continues to be consistent with a jet-circumnuclear interaction model.

106.65 — Accreting Supermassive Black Hole Binaries: Towards realistic EM Observables

Mark J. Avara[1]; Dennis Bowen[2]; Manuela Campanelli[1]; Scott C. Noble[3]; Julian Krolik[4]; Vassilios Mewes[1]

[1] *Center for Computational Relativity and Gravitation, RIT (Pittsford, New York, United States)*

[2] *LANL (Los Alamos, New Mexico, United States)*

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

[4] *JHU (Baltimore, Maryland, United States)*

Due to their geometrical complexity and widely discrepant temporal and physical scales, simulating fully global magnetized accretion onto black hole binaries during inspiral has been an ongoing challenge, especially to produce simulations with enough orbits to reach inflow quasi-equilibrium and identify potentially observable characteristics unique to black hole binaries, distinguishing them from lone AGN. Such signatures could potentially provide uniquely robust identification of binary AGN in current and future surveys. We report on our ongoing effort to use PatchworkMHD, a new multi-mesh/multi- physics engine for simulating astrophysical systems, to produce global 3D-GRMHD simulations of accreting supermassive black hole binaries that evolve for 10s of orbits with post-Newtonian space-time evolution (including resolving the event horizons). This is a step towards producing self- consistent synthetic many-orbit light curves and time-dependent spectra, and will be key in identifying binary supermassive black holes in near-term and future time-domain observations.

106.66 — Tiny charge - small mass - big effect: the onset of chaos near accreting black holes

Vladimir Karas[1]; Ondrej Kopacek[1]; Andreas Eckart[2,3]; Michal Zajacek[4]

[1] *Astronomical Institute (Prague, Czechia)*

[2] *I. Physikalisches Institut der Universitaet zu Koeln (Cologne, Germany)*

[3] *Max-Planck-Institut f. Radioastronomie (MPIfR) (Bonn, Germany)*

[4] *Center for Theoretical Physics, Polish Academy of Sciences (Warsaw, Poland)*

Within the framework of classical General Relativity the motion of particles near a rotating (Kerr) black hole is strictly regular. However, even a small perturbation by the surrounding matter can trigger the onset of chaos. The particle motion and acceleration then exhibit very diverse characteristics and the acceleration efficiency. In this context we examine the role of electric charging and self-gravity of a gaseous/dusty torus in strong gravity of a supermassive black hole magnetosphere. While the central black hole dominates the gravitational field and remains electrically almost neutral, the surrounding material has non-negligible self-gravitational impact on the torus structure and the acceleration of particles in the corona. These influences need to be taken into account to achieve a self-consistent picture.

106.67 — Physical Scenarios for Changing-Look Quasars

Daniel Stern[1]; Barry McKernan[2]; Matthew J. Graham[3]; K. E.S. Ford[2]; Nicholas P. ross[4]

[1] *JPL/Caltech (Altadena, California, United States)*

[2] *CUNY/AMNH (New York City, New York, United States)*

[3] *Caltech (Pasadena, California, United States)*

[4] *University of Edinburgh (Edinburgh, United Kingdom)*

As a touchstone for discussing the physics of changing-look quasars, we present the WISE J105203.55+151929.5, which was identified as a highly mid-IR variable quasar in the WISE/NEOWISE data stream. Compared to multi-epoch mid- IR photometry of a large sample of SDSS-confirmed quasars, this source is an extreme photometric outlier, fading by more than a factor of two at 3.4 and 4.6 um since 2009. Swift target-of-opportunity observations in 2017 show even stronger fading in the soft X-rays compared to the ROSAT detection of this source in 1995, with at least a factor of fifteen decrease. We obtained second-epoch spectroscopy with the Palomar telescope in 2017 which, when compared with the 2006 archival SDSS spectrum, reveals that the broad H-beta emission has vanished and that the quasar has become significantly redder. The two most likely interpretations for this dramatic change are source fading or obscuration, where the latter is strongly disfavored by the mid-IR data. We discuss various physical scenarios that could cause such changes in the quasar luminosity over this timescale, and favor changes in the innermost regions of the accretion disk that occur on the thermal and heating/cooling front timescales. We discuss possible physical triggers that could cause these changes.

106.68 — The deepest look at the accretion process with a 2 mega-second observation of a highly variable active galaxy

William Alston[1]; Andrew Fabian[1]; Douglas Buisson[1]; Erin Kara[1]; Michael Parker[1]; Anne Lohfink[1]; Phil Uttley[1]; Daniel Wilkins[1]; Ciro Pinto[1]; Barbara De Marco[1]; Matthew Middleton[1]; Edward Cackett[1]; Dom Walton[1]; Chris Reynolds[1]; Jiachen Jiang[1]; Luigi Gallo[1]; Abderahmen Zoghbi[1]; Giovanni Miniutti[1]; Michal Dovciak[1]; Andy Young[1]

[1] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*

The fast timing properties of accreting black hole light curves allow us to probe the direct vicinity of black holes, the region most affected by strong gravity. We present an extensive X-ray variability analysis from the longest XMM-Newton observation taken to date, with 2 mega-seconds on the highly variable Seyfert 1 galaxy, IRAS 13224-3809. This long observation has revealed new and complex underlying variability processes. We will show modelling of the coronal and reverberation delays using GR ray tracing models. This allows us to build up the most detailed picture to date of the inner X-ray emitting regions of AGN. We discuss the implication of these results for accreting sources across the mass range.

106.69 — MUlti-ZOne Radiation Feedback modeling of Mrk 421 during a violent outburst in February 2010

Manasvita Joshi[1]; Biswajit Banerjee[3]; Pratik Majumdar[3]; Karen Williamson[1]; Svetlana Jorstad[1,2]; Alan Marscher[1]

[1] *Department of Astronomy, Boston University (Boston, Massachusetts, United States)*

[2] *Astronomical Institute, St. Petersburg University (St. Petersburg, Russian Federation)*

[3] *Saha Institute of Nuclear Physics (Kolkata, India)*

We present the results of comprehensive time-dependent modeling of Mrk 421 in internal shock scenario using a MUlti-ZOne Radiation Feedback (MUZORF) scheme. MUZORF calculates blazar jet emission as a result of various radiative mechanisms, such as synchrotron, synchrotron self-Compton, and external Compton. It addresses the inhomogeneity in photon and particle populations in the region by slicing a cylindrical emission region into multiple zones and providing radiation feedback to adjacent zones. We have applied MUZORF separately to three spectral states of MRk 421 that were observed during a violent outburst in February 2010. Our results indicate that a particle population following a simple power-law and distributed in an inhomogeneous cylindrical emission region is capable of reproducing the spectral behavior of Mrk 421 in February 2010. However, departure from equipartition is required along with an emergence of a general trend, according to which the magnetic field strength declines and the particle population becomes energetic and harder as the flare evolves and attains its peak in the third and final spectral state.

This research was supported in part by NASA through Fermi grant 80NSSC17K0650.

106.70 — Analysis of a Bright Orphan Gamma-Ray Flare from 3C 279

Tiffany Lewis[1,2]; Justin Finke[3]; Peter Becker[4]
[1] *Tel Aviv University (Tel Aviv, Israel)*
[2] *University of Haifa (Haifa, Israel)*
[3] *US Naval Research Laboratory (Washington, District of Columbia, United States)*
[4] *George Mason University (Fairfax, Virginia, United States)*

Multiwavelength observations of the blazar 3C 279 show a very bright, 12-hour, orphan gamma-ray flare on 20 Dec 2013 with a uniquely hard FermiLAT spectrum and high Compton dominance. We work with a one-zone, leptonic model with both first- and second-order Fermi acceleration, which now reproduces the unique flaring behavior. We present a simplified analytic particle distribution to provide intuition about how acceleration shapes blazar spectra since understanding contributions of individual n processes in blazar jets is fundamental to our understanding of the particle energy budget in the disk-jet connection.n We rule out the possibility that significant acceleration occurs via magnetic reconnection due to the very low magnetization parameter, and is constrained by the maximum Larmor radius for the jet geometry. We propose that larger changes in the surrounding material precipitated this unusual flare exacerbated the emission from moderate increases in acceleration, especially an increased energy density in the broad line region and dust torus, as well as an increase in jet material, which lowered the synchrotron radiation as Compton emission soared.

106.71 — Correlations between Optical/Infrared and Gamma-ray Variability for Bright Blazars Monitored in 2008-2017

Kenji Yoshida[1,2]; Charles Bailyn[2]; Bryndis Cruz[2]; C. Meg Urry[2]; Paolo Coppi[2]; Georgios Vasilopoulous[2]; Maria Petropoulou[3]
[1] *Shibaura Institute of Technology (Saitama, Japan)*
[2] *Yale University (New Haven, Connecticut, United States)*
[3] *Princeton University (Princeton, New Jersey, United States)*

We report the results of cross correlations of the SMARTS optical/infrared and Fermi-LAT gamma-ray light curves for 8 bright blazars that have been monitored with 1 day resolution over the past decade. For the temporal correlation analysis of unevenly sampled variability data, we use the Discrete Correlation Function (DCF), creating an empirical bootstrapping method to assess the significance of the DCF amplitude for each blazar. Our results are perhaps surprising. Early on in the Fermi mission, the brightest gamma-ray blazar 3C 454.3 showed zero lag between optical/infrared and gamma-ray fluxes as reported by Bonning et al. (2012), which was consistent with the leptonic model that optical/infrared photons are produced by synchrotron radiation of relativistic electrons and gamma rays are produced by inverse Compton scattering of ambient photons by the synchrotron-emitting electrons. However, among the 8 blazars, only one blazar - 3C 454.3 - shows a significant peak at zero lag, and the other 7 blazars show no significant peak at zero lag. Some blazars show broad peaks at tens of days of lags at or just below 3 sigma significance. In addition, for a given blazar, strong changes of the DCFs from one epoch to the next are shown by the analyses of time periods of one or two year. These results make it complicated to understand blazar emission mechanisms. We discuss possible physical explanations.

106.72 — Characterizing the gamma-ray variability of the brightest flat spectrum radio quasars observed with the Fermi LAT

Manuel Meyer[1]; Roger Blandford[1]; Jeffrey Scargle[2]
[1] *KIPAC, Stanford University (Stanford, California, United States)*
[2] *NASA Ames Research Cente (Moffett Field, California, United States)*

Almost 10 years of observations with the Fermi Large Area Terlescope (LAT) have revealed extreme gamma-ray outbursts from flat spectrum radio quasars (FSRQs), temporarily making these objects the brightest gamma-ray emitters in sky. Yet, the location and mechanisms of the gamma-ray emission remain elusive. Here, we characterize the brightest flares of six FSRQs observed with the LAT. We find evidence for variability on timescales as short as minutes in four sources, which suggests that extremely compact emission regions are a common feature in FSRQs. We do not find any signs for gamma-ray absorption in the broad line region (BLR), which indicates that the gamma-rays are produced away from the black hole by hundreds of gravitational radii. This is further supported by a correlation analysis between radio and gamma-ray light curves. We propose two possible scenarios, which we will quantitatively investigate in the future, that could explain these observations: the gamma-ray emission region might be screened from BLR photons or the gamma rays could be synchrotron emission from electron-positron pairs produced by proton interactions in the BLR.

106.73 — Probing the physics of cosmological gamma-ray propagation with the Cherenkov Telescope Array

Manuel Meyer[1]
[1] *KIPAC, Stanford University (Stanford, California, United States)*

Gamma rays emitted by active galaxies offer the unique opportunity to study the propagation of very-high-energy photons over cosmological distances. They interact with the extragalactic background light (EBL) to produce electron- positron pairs, imprinting an attenuation signature on gamma-ray spectra. The pairs can subsequently initiate electromagnetic cascades whose gamma-ray signature depends on the intergalactic magnetic field (IGMF). Furthermore, physics beyond the Standard Model such as Lorentz invariance violation (LIV) or oscillations between photons and weakly interacting sub-eV particles (WISPs) could lead to distinct features in gamma-ray spectra. The future Cherenkov Telescope Array (CTA), with its unprecedented gamma-ray source sensitivity, as well as enhanced energy and spatial resolution, is perfectly suited to study cosmological effects on gamma-ray propagation. Here, we present first results of the capabilities of CTA to probe the EBL, IGMF, LIV, and WISPs.

107 — Galaxy Clusters/Large Scale Structures Poster Session

107.01 — REVEALING A HIGHLY-DYNAMIC CLUSTER CORE IN ABELL 1664 WITH CHANDRA

Michael Calzadilla[1,3]*; Helen Russell*[2]*; Michael McDonald*[1]*; Andrew Fabian*[2,3]*; Stefi Bau*[4]*; Francoise Combes*[5]*; Megan Donahue*[6]*; Alastair Edge*[7]*; Brian McNamara*[8]*; Paul Nulsen*[9]*; Christopher O'Dea*[4]*; Raymond Oonk*[10]*; Grant Tremblay*[9]*; Adrian Vantyghem*[8]
[1] *Department of Physics, Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*
[2] *SURFsara (Amsterdam, Netherlands)*
[3] *Institute of Astronomy (Cambridge, United Kingdom)*
[4] *University of Cambridge (Cambridge, United Kingdom)*
[5] *University of Manitoba (Winnipeg, Manitoba, Canada)*
[6] *Observatoire de Paris (Paris, France)*
[7] *Michigan State University (Lansing, Michigan, United States)*
[8] *Durham University (Durham, United Kingdom)*
[9] *University of Waterloo (Waterloo, Ontario, Canada)*
[10] *Center for Astrophysics (Cambridge, Massachusetts, United States)*

We present new, deep (245ks) Chandra observations of the galaxy cluster Abell1664 (z=0.1283). These images reveal rich structure, including elongation and accompanying compressions of the X-ray isophotes in the NE-SW direction, suggesting that the hot gas is sloshing in the gravitational potential. This sloshing has resulted in cold fronts, at distances of 50, 110 and 325 kpc from the cluster center. Our results indicate that the core of Abell 1664 is highly disturbed, as the global metallicity and cooling time flatten at small radii, implying mixing on a range scales. The central AGN appears to have recently undergone a mechanical outburst, as evidenced by our detection of cavities. These cavities are the X-ray manifestations of radio bubbles inflated by the AGN, and may explain the motion of cold molecular clouds previously observed with ALMA. The estimated mechanical power of the AGN is $1.1 \pm 1.0 \times 10^{44}$ erg/s, which may be enough to drive the molecular gas flows, and offset the cooling luminosity of the ICM ($L_{cool} \sim 1.53 \times 10^{44}$ erg/s). This mechanical power is orders of magnitude higher than the measured upper limit on the X-ray luminosity of the central AGN, suggesting that its black hole may be extremely massive and/or radiatively inefficient. We map temperature variations on the same spatial scale as the molecular gas, and find that the most rapidly cooling gas is mostly coincident with the molecular gas reservoir centered on the BCG's systemic velocity observed with ALMA and may be fueling cold accretion onto the central black hole.

107.02 — Probing Non-Thermal Pressure Support in Galaxy Cluster Outskirts using Synthetic X-ray Observations

Urmila Chadayammuri[1,2]; Daisuke Nagai[2]; Esra Bulbul[1]; Vittorio Ghirardini[1]
[1] *High Energy Astrophysics Division, Chanda X-Ray Center (Somerville, Massachusetts, United States)*
[2] *Yale University (New Haven, Connecticut, United States)*

The outskirts of galaxy clusters are dynamically active regions, with accretion from cosmic filaments resulting in bulk and turbulent gas motions throughout the virialization regions. These offer a source of non-thermal pressure support against gravity to the X-ray emitting intracluster gas and introduce biases in cluster masses estimates. Over the next two decades, X-ray imaging and spectroscopy missions promise to provide new measurements of bulk and turbulent motions using shifting and broadening of X-ray spectral lines as well as surface brightness fluctuations. The upcoming XRISM mission, for example, will provide detailed measurements of bulk and turbulent motions in cluster cores in nearby clusters. However, it remains particularly challenging to measure bulk and turbulent motions in faint cluster outskirts, where the X-ray surface brightness is several orders of magnitude lower than in the core. The next generation of instruments, such as Athena's X-IFU and Lynx, will have the effective area and spectral and spatial resolutions required to perform these measurements. In this work, we investigate the nature of bulk and turbulent gas motions from cores to outskirts of galaxy clusters, by analyzing mock X-ray spectral and imaging observations of the simulated galaxy cluster extracted from the RomulusC simulation, the highest-resolution hydrodynamical cosmological simulation of a galaxy cluster to date. We make predictions for XRISM, Athena and Lynx missions and discuss strategies and prospects for constraining the nature of bulk and turbulent motions as well as implications for the use of galaxy clusters as cosmological probes.

107.03 — Mapping the outer parts of galaxy clusters combining X-ray and SZ observations

Vittorio Ghirardini[1]
[1] *Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

The hot plasma of the Intracluster medium (ICM) that we observe today was heated through shocks and adiabatic compression during the processes leading to the thermalization of the gas inside the gravitational potential of massive galaxy cluster. The theromdynamical properties of this gas encode information on these non-gravitational processes, such as gas cooling, AGN feedback, shocks, turbulence, bulk motions, cosmic rays, and magnetic field. I will describe how I have exploited the synergy between XMM-Newton and Planck, thus combining X-ray and Sunyaev-Zel'dovich (SZ) observations, to study the outskirts of a mass selected sample of low redshift clusters, the X-COP sample, measuring thermodynamic quantities out to 2 R500. I will demonstrate how the outskirts in these clusters are regular and self-similar, I will show what is the intrinsic scatter as function of radius, and how the relation between pressure and density resembles a single polytropic relation with very little scatter. In particular, I will also explore how these results allow to rediscover a model to describe all the thermodynamic properties in the outskirts of galaxy clusters with only few parameters, 2 parameters in common to all thermodynamics and 4 normalizations, one for each thermodynamic property. Then I will connect to an SPT sample of high redshift clusters, and I'll link the properties of these two cluster samples, from the first clusters formed in our Universe, to the ones we observe today at low redshift, thus tracing the evolution with cosmic time of the observable properties of galaxy clusters.

107.04 — Forecasting Angular Cross Correlations Between Diffuse X-ray Emission and the Thermal Sunyaev-Zel'dovich Effect

Vincent Lakey[1]; Kevin Huffenberger[1]
[1] *Department of Physics, Florida State University (Tallahassee, Florida, United States)*

X-ray emission and the thermal Sunyaev-Zel'dovich distortion to the Cosmic Microwave Background are two important handles on the gas content of the Universe. The cross-correlation between these effects eliminates noise bias and reduces observational systematic effects. We developed a halo model formalism to study this cross-correlation and apply it to forecast the signal- to-noise of upcoming measurements from eROSITA and the Simons Observatory. We model the gas pressure, electron density, temperature, and clumping with Battaglia et al. profile fits to hydrodynamical simulations. We model the X-ray emissivity using the Astrophysical Plasma Emission Code (APEC) and include both continuum and line emission. The model reproduces a reasonable value for the mean X-ray background with no additional tweaking. In the soft X-ray band (0.5-2 keV), we forecast a signal-to-noise of 176 for the cross- power spectrum. Over a wide range of the scales, the X-rays will be signal- dominated, and so sample variance is important. In particular, non-Gaussian (4-point) contributions to the errors highlight the utility of masking massive clusters. Masking clusters down to 10^{14} solar masses increases the signal- to-noise of the cross-spectrum to 209. We perform a Fisher Analysis on the fitting coefficients of the Battaglia et al. gas profiles and on cosmological parameters. We find that the cross spectrum is most sensitive to the overall scale of the halo pressure and electron density profiles as well as cosmological parameters sigma 8 and H0, but that the large number of parameters form a degenerate set, which makes extracting the information more challenging. Our modeling framework is flexible, and in the future, we can easily extend it to forecast the spatial cross-correlations of surveys of X-ray lines available to high-energy-resolution microcalorimetry, and to studies of the Warm-Hot Intergalactic Medium, among other effects.

107.05 — Galaxy Kinematics as a Function of Environment within the ORELSE Survey

Debora Pelliccia[1,2]
[1] *University of California at Davis (Davis, California, United States)*
[2] *University of California at Riverside (Riverside, California, United States)*

It is still a matter of debate how galaxies assemble their total mass, and which role each component (stars, gas, and dark matter) plays in this process. Galaxy internal kinematics can help in this respect, since it traces the galaxy's dynamical (i.e., total) mass, including both luminous and dark matter. Moreover, the environment in which galaxies reside is critical in determining their evolutionary path, as, once galaxies enter a group or cluster environment, they are subject to many processes, like mergers and ram pressure stripping to name a few, which do not exist or are less common in field environments. Almost any observable property of a galaxy (e.g., morphology, colors, star formation) demonstrates some association with environment, but it is not clear whether environment is as effective at influencing galaxy kinematics as it is for other galaxy properties. I will present the results obtained by studying the effect of the environment on the well-established stellar-mass Tully-Fisher relation, the stellar-to-dynamical mass ratio and specific angular momentum for a sample of galaxies at redshift $0.6<z<1.3$ drawn from the ORELSE survey, a large multi-wavelength photometric and spectroscopic campaign dedicated to map out and characterize galaxy properties in 15 fields which contain large-scale structures. I will show how comparing these results to hydrodynamical simulations and semi- empirical models helps to infer the merging history of galaxies entering dense environments.

107.06 — Characterizing the Hot Halos of Galaxy Groups and Clusters with X-ray and SZ Observations

Cameron Pratt[1]*; Joel N. Bregman*[1]
[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

X-ray observations have been used to characterize the gaseous halos of galaxy groups and clusters, but many of the derived quantities assume the gas is in hydrostatic equilibrium. While this assumption can be applied to relaxed systems, it becomes invalid for those not in a virialized state. Accordingly, there will be a spread in the amount of relaxation for galaxy groups/clusters within various mass bins. We evaluate this distribution by cross-correlating X-ray data with observations of the Sunyaev-Zel'dovich (SZ) effect. This study uses data from the *ROSAT* All-Sky Survey (RASS) near the north ecliptic pole, where the satellite attained its deepest exposure, and the SZ maps from the *Planck* mission. These two independent probes of the same hot gas allow us to estimate various group/cluster properties, such as the baryon fraction and the variation in gas mass spanning a halo mass range of 10^{13}-10^{15} solar masses. In addition, we will catalog and inspect any groups/clusters with a detected SZ signal that are not identified in the RASS dataset; some of these objects may call for deeper X-ray observations in the future.

107.07 — Using Hα Filaments to Probe AGN Feedback in Galaxy Clusters

Yu Qiu[1]*; Tamara Bogdanovic*[1]*; Yuan Li*[2]*; Michael McDonald*[3]
[1] *Georgia Institute of Technology (Atlanta, Georgia, United States)*
[2] *University of California, Berkeley (Berkeley, California, United States)*
[3] *Massachusetts Institute of Technology (Boston, Massachusetts, United States)*

Recent observations of giant ellipticals and brightest cluster galaxies (BCGs) provide tentative evidence for a correlation between the luminosity of the Hα emitting gas filaments and the strength of feedback associated with the active galactic nucleus (AGN). Motivated by this, we use 3D radiation- hydrodynamic simulations with the code Enzo to examine and quantify the relationship between the observable properties of the Hα filaments and the kinetic and radiative feedback from supermassive black holes in BCGs. We find that the spatial extent and total mass of the filaments show positive correlations with AGN feedback power and can therefore be used as probes of the AGN activity. We also examine the relationship between the AGN feedback power and velocity dispersion of the Hα filaments and find that the kinetic luminosity shows a statistically significant correlation with the component of the velocity dispersion along the jet axis, but not the components perpendicular to it.

107.08 — Merging Galaxy Clusters, Cluster Outskirts, and Large Scale Filaments

Scott Randall[1]; Gabriella Alvarez[2,1]; Rachel Paterno-Mahler[3]; Yuanyuan Su[4]; Esra Bulbul[1]; William R. Forman[1]; Christine Jones[1]

[1] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

[2] *Vanderbilt University (Nashville, Tennessee, United States)*

[3] *West Los Angeles College (Culver City, California, United States)*

[4] *University of Kentucky (Lexington, Kentucky, United States)*

X-ray observations of the outskirts of galaxy clusters show that the entropy of the intracluster medium (ICM) in the virialization region is generally less than what is expected based on purely gravitational structure formation. Possible explanations include electron/ion non-equilibrium, accretion shocks that weaken during cluster formation, and the presence of unresolved cool gas clumps. Some of these mechanisms are expected to correlate with large scale structure (LSS), such that the entropy is lower in regions where the ICM interfaces with LSS filaments and, presumably, the warm-hot intergalactic medium (WHIM). Major, binary cluster mergers are expected to take place at the intersection of LSS filaments, with the merger axis initially oriented along a filament. We present results from deep X-ray observations of the virialization regions of binary, early-stage merging clusters, including a possible detection of the dense end of the WHIM along a LSS filament.

107.09 — NuSTAR Observations of ABELL 2163: Constraining Non-Thermal Emission

Randall Alfonso Rojas Bolivar[1]; Daniel Wik[1]

[1] *Department of Astronomy, University of Utah (Salt Lake City, Utah, United States)*

Since the first non-thermal detections of Inverse Compton (IC) emission in galaxy clusters at hard X-ray energies, we have yet to unambiguously confirm IC in follow-up observations. Claims of large IC fluxes from the 10′ extent of Abell 2163, a massive merging cluster at z = 0.2, make it the next best chance of confirming a previous IC detection with NuSTAR. Additionally, recently available deep XMM data indicate extreme temperature variations (10-20 keV), the hottest of which are likely due to shocks. However, the XMM spectra suffer from variable Galactic absorption across the cluster, which can be avoided with NuSTAR's harder energy band. We find that the global NuSTAR spectrum is consistent with pure thermal emission, with a global temperature of 11.77 keV ± 0.13 keV. Our model provides a constraint on IC emission of 1.62×10^{-12} erg s^{-1} cm^{-2} as well as a value for the magnetic field of the cluster, B > 0.22 μG or B > 0.35 μG using the normalization obtained from a nine temperature model.

107.10 — Electron heating and acceleration in non-relativistic shocks

Anatoly Spitkovsky[1]; Rui Xu[1]; Vassilis Tsiolis[1]

[1] *Princeton University (Princeton, New Jersey, United States)*

Nonrelativistic collisionless shocks, such as those in supernova remnants and galaxy clusters, can, under certain conditions, act as efficient accelerators of protons and electrons, and can equilibrate the temperatures between the species. Using ab-initio particle-in-cell simulations we investigate the structure of magnetized nonrelativistic shocks and measure the ratio of electron to ion temperature and non-thermal fraction for a range of shock Mach numbers and magnetic inclination angles. We find that quasi- perpendicular shocks generally transfer no less than 10% of energy from ions to thermal electrons in the downstream, and is often near equipartition. This is much larger than the naive expectation of the 1/1836 electron-ion temperature ratio in a two-component collisionless shock with no extra energy transfer. We also find that particle acceleration in quasi-perpendicular geometry is limited primarily to electrons. Such shocks can reflect several percent of electrons due to magnetic mirroring, and the reflected electorn stream can grow upstream turbulence that leads to full diffusive shock acceleration. Such lepton-only accelerators and collisionless equilibration are interesting for interpreting galaxy cluster shocks and for supernova remnant morphology studies.

107.11 — Extended X-ray Study of M49: The Frontier of the Virgo Cluster

Yuanyuan Su[1,2]; Ralph Kraft[2]; Paul Nulsen[2]; Christine Jones[2]; Thomas J. Maccarone[3]; William R. Forman[2]

[1] *University of Kentucky (Lexington, Kentucky, United States)*

[2] *Center for Astrophysics | Harvard-Smithsonian (Cambridge, Massachusetts, United States)*

[3] *Texas Tech University (Lubbock, Texas, United States)*

The M49 group, residing outside the virial radius of the Virgo cluster, is falling onto the cluster from the south. We report results from deep XMM- Newton mosaic observations of M49. Its hot gas temperature is 0.8keV at the group center and rises to 1.5keV beyond the brightest group galaxy (BGG). The group gas extends to radii of ∼ 300 kpc to the north and south. The observations reveal a cold front ∼ 20 kpc north of the BGG center and an X-ray bright stripped tail 70 kpc long and 10 kpc wide to the southwest of the BGG. We argue that the atmosphere of the infalling group was slowed by its encounter with the Virgo cluster gas, causing the BGG to move forward subsonically relative to the group gas. We measure declining temperature and metallicity gradients along the stripped tail. The tail gas can be traced back to the cooler and enriched gas uplifted from the BGG center by buoyant bubbles, implying that AGN outbursts may have intensified the stripping process. Magnetic shielding from the group gas needs to be invoked to maintain the high pressure and the low entropy of the extended tail. Its group atmosphere appears truncated and deficient when compared with isolated galaxy groups of similar temperatures. If M49 is on its first infall to Virgo, the infall region of a cluster could have profound impacts on galaxies and groups that are being accreted onto galaxy clusters. Yet, M49 may have already passed through Virgo once.

107.13 — Evidence for earlier formation epochs of fossil groups of galaxies: the case for J100742.53+380046.6

Renato A. Dupke[1]; Yolanda Jimenez-Teja[2,3]; Yuanyuan Su[4]; Anton Koekemoer[5]; Jimmy Irwin[6]; Lucas Johnson[6]; Eric Miller[7]; Rodrigo Carrasco[8]

[1] *EurekaScientific, Univ. Michigan, Nat. Obs (Ann Arbor, Michigan, United States)*

[2] *Nat. Obs. Brazil (Rio de Janeiro, Rio de Janeiro, Brazil)*

[3] *IAA (Granada, Andalusia, Spain)*

[4] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

[5] *STSCI (Baltimore, Maryland, United States)*

[6] *Univ. of Alabama (Tuscaloosa, Alabama, United States)*

[7] *MIT (Cambridge, Massachusetts, United States)*

[8] *Gemini Obs./AURA (La Serena, Chile)*

Fossil groups of galaxies still present a puzzle to theories of structure formation. Despite the low number of bright galaxies, their have relatively high velocity dispersions and IGM temperatures corresponding to cluster-like potential wells. Their measured c200 are high indicating early formation epochs in contradiction with the observed lack of expected well developed cool cores. We have recently proposed an independent age discriminatory test, using a recently found cluster dynamical indicator in the intracluster light color distribution and its ratio to cluster's mass. We present here the preliminary results using HST and XMM data for J100742.53+380046.6.

107.14 — Radio Relic Formation In The Cluster PLCKSZ G200.9-28.2: A Search for Shocks

Sarina Etheridge[1]; Daniel Wik[1]

[1] *Department of Physics and Astronomy, University of Utah (Salt Lake City, Utah, United States)*

Galaxy clusters are the largest virialized structures in the universe, growing in size by merging together via violent collisions, arguably the most energetic events since the Big Bang. Mergers heat the tenuous gas by turbulence and shock fronts driven by the dark matter. Shocks are difficult to study directly due to their intrinsically low Mach numbers and short life spans, and as such are rare events to observe. However, key features such as radio relics produced by synchrotron-emitting relativistic electrons, temperature variations, and surface brightness discontinuities often coincide with their location. PLCKSZ G200.9-28.2 is a cluster undergoing a current merger, discovered through the Sunyaev-Ze'ldovich effect by the Planck satellite, and has shown evidence to have a radio relic in its outskirts. Interestingly, this radio relic is oriented at an angle ∼45 degrees to the merger axis, instead of the typical 90 degrees, possibly providing evidence for a complicated multiple-merger scenario. We present new, deep (142 ks) observations of this cluster with the Chandra X-ray Observatory, including surface brightness profiles and temperature maps to better understand the nature of the merger, and locate the possible presence of shock fronts both in the northern subcluster and along the radio relic.

107.15 — RXTE Clusters of Galaxies: Test of Atomic Database 3.0.9

Richard E. Rothschild[1]; Yoel Rephaeli[1]
[1] *Center for Astrophysics and Space Sciences, University of California, San Diego (Solana Beach, California, United States)*

The Rossi X-ray Timing Explorer observed 16 clusters of galaxies during its 16 year mission. We have summed all of Proportional Counter Array (PCA) individual observations of each cluster , and generated source and background files utilizing the final calibrations and background estimates. Each clusters' spectra were fitted with the APEC model supported by the atomic database (3.0.9), which has been updated based on the Hitomi observation of the Perseus cluster. In 8 of the spectra, significant residuals were seen in the 6-7 keV band. A simple thermal bremsstrahlung continuum plus two redshifted Gaussians at ~6.7 keV and ~7.9 keV yielded good fits, implying that the residuals were not due to the PCA modest energy resolution. These results, plus comparisons to reported non-thermal power law components, will be reported.

107.16 — The Abell 1758 quadruple merger: forming one of the most massive clusters

Jan M. Vrtilek[1]; Gerrit Schellenberger[1]; Laurence David[1]; Ewan O'Sullivan[1]; Christopher Haines[2]
[1] *High Energy Astrophysics Division, Center for Astrophysics (Cambridge, Massachusetts, United States)*
[2] *University of Birmingham (Birmingham, United Kingdom)*

We report on analysis of Chandra data of Abell 1758, a system that can be subdivided into a bigger and more massive northern cluster and a smaller southern cluster. Both parts are undergoing major merger events at different stages. This complex system offers the opportunity to study many merger- related phenomena, such as the impact of the merger on the gas in clusters, occurrence of shocks and cold fronts, radio halos and relics, and the interaction between clusters at a very early stage of the merging process (N and S). By combining deep Chandra with XMM and GMRT data, we can now characterize the mergers in the Abell 1758 system in greater detail than has been possible before. We find: (1) Although the mass of the merger constituents provides enough energy to produce visible shock fronts in the X-ray, none have been found hitherto. Now we detect a shock front in Abell 1758 N with a Mach number ($M \approx 1.6$) that is consistent with derivation from the density and temperature discontinuities. The implied relative merger velocity is about 2100 km/s. (2) Non-thermal radio emission observed with the GMRT confirms the presence of radio halos in the northern and southern clusters, and shows evidence for a relic in the periphery of the southern cluster. Additionally, we provide new hydrostatic mass measurements, present detailed temperature and abundance maps based on recent Chandra ACIS data, and explore the effects of the merger on the distribution of heavy elements.

107.17 — J-PAS/eROSITA Joint Cluster/AGN Survey

Renato A. Dupke[1]; Alexis Finoguenov[2]; Jimmy Irwin[3]; Silvia Bonoli[4]; Raimundo Lopes De Oliveira[5]; Javier Cenarro[6]; Antonio Marín Franch[7]; Raul Abramo[8]; Jose Vilchez[9]; JPAS Collaboration[10]
[1] *EurekaScientific,UM,ON (Ann Arbor, Michigan, United States)*
[2] *ON/IAG/CEFCA/IAA (Rio/SP/Teruel/Granada, Brazil)*
[3] *University of Helsinki (Helsinki, Finland)*
[4] *Univ. of Alabama (Tuscaloosa, Alabama, United States)*
[5] *Ikerbasque Basque Foundation for Science (San Sebastian, Spain)*
[6] *Federal Univ. of Sergipe (Aracaju, Brazil)*
[7] *CEFCA (Teruel, Spain)*
[8] *CEFCA (Teruel, Spain)*
[9] *Univ Sao Paulo (Sao Paulo, Brazil)*
[10] *Instituto de Astrofisica de Andalucia (Granada, Spain)*

The Javalambre-Physics of the Accelerated Universe Astrophysical Survey (J-PAS) is a narrow band, wide field Cosmological Survey to be carried out from the Javalambre Astrophysical Observatory in Spain with a purpose-built, dedicated 2.5m telescope and a ~5 sq.deg. camera with 1.2 Gpix. Starting in 2019, J-PAS plans to observe >8000sq.deg. of Northern Sky and measure sigma$_z$~0.003(1+z) photo-z for up to 9E7 LRG and ELG galaxies plus several million QSOs, sampling an effective volume of ~ 14 Gpc^3 up to z~1.3 reaching Stage IV radial BAO experiment. J-PAS is expected to detect ~7E5 galaxy groups and clusters, setting constraints on Dark Energy which rival those obtained from its BAO measurements. J-PAS will have an immense legacy value for almost all astrophysical areas. The key to the J-PAS potential is its innovative approach: a contiguous system of 54 filters with 145A width, placed 100A apart over a multi-degree FoV being a powerful "redshift machine", with the survey speed equivalent to a 4000 multiplexing low resolution spectrograph. eROSITA, to launch early this year, will detect the hot ICM/IGM of up to 1E5 clusters and groups and also will detect systematically all obscured accreting Black Holes in nearby galaxies and many (up to 3 Million) new, distant AGN. J-PAS- eROSITA synergy is optimal in both the studies of AGN and clusters of galaxies. It provides several unique aspects. First, precise measurement of redshift and clean identification. J-PAS data provide immediate identification. Compared to the broad-band photometric surveys, J-PAS is the best way to measure redshifts of AGN, and providing precise enough photo-z for the cluster member galaxies. The uniqueness of J-PAS data in providing the host galaxy properties is particularly interesting for AGN host studies, where narrow-band data are essential. In identifying of galaxy clusters, J-PAS will be uniquely sensitive towards low-mass counterparts, which are missed by the broad-band surveys, enabling cluster cosmology using broad range of cluster masses. Here we present the status of J-PAS, eROSITA and the potential scientific outcomes of the synergy.

107.18 — Chandra Follow-up of Dark Energy Survey Clusters Through Year 3

Lena Eiger[1,2]; Tesla Jeltema[1,2]
[1] *Department of Physics (Astrophysics), UC Santa Cruz (Santa Cruz, California, United States)*
[2] *Santa Cruz Institute for Particle Physics (Santa Cruz, California, United States)*

Analysis of galaxy clusters can help place constraints on the matter density of the universe and the dark energy equation of state. Cosmological parameters can be constrained through the evolution of the cluster mass function. While cluster mass can be observed using techniques such as weak lensing, many surveys do not have the necessary depth of data to observe mass directly. Stacked weak lensing techniques can be used to ascertain mean observable-mass relations, which themselves have intrinsic scatter distributions. Last year, the Mass Analysis Tool for Chandra (MATCha) was introduced (Hollowood et. al 2018) to analyze galaxy cluster mass proxies and their intrinsic scatter distributions using archival Chandra X-ray data. I will detail several upgrades to the MATCha pipeline, such as techniques for inferring temperature from unclear data and improvements to centering calculations. Finally, I will present MATCha analysis of Dark Energy Survey Year 3 clusters.

107.19 — XLSSC 122: Spectroscopic confirmation of a massive, mature cluster at z$\sim$2

Emil Noordeh[1]; Jon Willis[2]; Rebecca Canning[1]
[1] *Department of Physics, Stanford University (Stanford, California, United States)*
[2] *University of Victoria (Victoria, British Columbia, Canada)*

We present HST grism spectroscopy of XLSSC 122 confirming its redshift of z=1.98, making it the highest redshift, X-ray selected galaxy cluster discovered to date. This redshift is in good agreement with that derived from spectral fitting of the redshifted X-ray Fe 6.7 keV line. The cluster displays a well defined red sequence as well as significant star formation and AGN activity in the confirmed cluster members. Here we present a multi-wavelength analysis of the cluster properties as well as stellar population modelling and emission line analysis of the cluster member population.

107.20 — The Clusters Hiding in Plain Sight (CHiPS) Survey

Taweewat Somboonpanyakul[1]; Michael McDonald[1]
[1] *Department of Physics, Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*

In this poster, I will introduce the Cluster Hiding in Plain Sight (CHiPS) survey with the aim to discover new galaxy clusters surrounding X-ray-bright point sources. The CHiPS survey is designed around the idea that the centrally concentrated galaxy clusters or clusters hosting central QSOs can be misidentified as field active galactic nuclei (AGN) in previous all-sky surveys. I will present our first newly discovered galaxy cluster, surrounding the quasar PKS1353-341, at z = 0.223, along with new Chandra observations of the galaxy cluster and its central AGN. We have also completed the optical follow-ups of the CHiPS targets and were recently awarded Chandra observations of the 5 promising candidates. One of these candidates shows a significant signal to be another new discovery. By performing a detailed study of these objects, we can investigate the impact a central quasar has on the intracluster medium and demonstrate the potential of the CHiPS survey to find massive nearby clusters with extreme central properties that may have been misidentified by previous surveys.

107.21 — The Complete Local-Volume Groups Sample (CLoGS): progress in X-ray, radio continuum, and CO line observations

Jan M. Vrtilek[1]; Ewan O'Sullivan[1]; Konstantinos Kolokythas[2]; Laurence David[1]; Gerrit Schellenberger[1]; Francoise Combes[3]; philippe salome[3]
[1] *High Energy Astrophysics Division, Center for Astrophysics (Cambridge, Massachusetts, United States)*
[2] *IUCAA (Pune, India)*
[3] *Observatoire de Paris (Paris, France)*

The Complete Local-Volume Groups Sample (CLoGS) was created in response to the lack of unbiased galaxy group samples and is designed to avoid the selection biases generally present particularly in X-ray selected samples (strongly biased in favor of the X-ray bright, centrally-concentrated cool-core systems). This statistically-complete sample of 53 groups within 80 Mpc is intended to serve as a representative survey of groups in the local Universe. In addition to X-ray data from Chandra and XMM (100% complete at this point, using both archival and new observations), we have added GMRT radio continuum observations (at 235 and 610 MHz, complete for the entire sample) and IRAM 30 m and APEX telescope observations of CO(1-0) and CO(2-1) lines (complete for the group-dominant early-type galaxies in the sample). We find that 14 of the 26 high-richness groups are X-ray bright, and that ∼53–65 per cent of the X-ray bright groups have cool cores, a somewhat lower fraction than found by previous archival surveys. Approximately 30 per cent of the X-ray bright groups show evidence of recent dynamical interactions (mergers or sloshing), and ∼35 per cent of their dominant early-type galaxies host active galactic nuclei with radio jets. In the 26 high-richness groups, 92% of the dominant galaxies host detected radio sources, with a four order- of-magnitude range in luminosities. Roughly half are point-like, with another quarter hosting jets and most of the rest showing a diffuse morphology. Jet sources are more common in X-ray bright groups, with radio non-detections found only in X-ray faint systems. We find that central AGN are not always in balance with cooling, but may instead produce powerful periodic bursts of feedback heating. Of the 53 CLoGS dominant galaxies, 21 are detected in CO and we confirm our previous findings that they have low star formation rates (0.01–1 Msun/yr) but short depletion times (<1 Gyr) implying rapid replenishment of their gas reservoirs. A much higher fraction of our group- dominant galaxies (∼60%) are AGN-dominated than is the case for the general population of ellipticals.

108 — ISM/Galaxies Poster Session

108.01 — Discovery of the hottest component of the Milky Way circumgalactic medium with non-solar abundance ratios

Sanskriti Das[1]; Smita Mathur[1]; Fabrizio Nicastro[2,3]; Yair Krongold[4]

[1] *Department of Astronomy, The Ohio State University (Columbus, Ohio, United States)*

[2] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

[3] *Observatorio Astronomico di Roma (Rome, Italy)*

[4] *Instituto de Astronomia, Universidad Nacional Autonoma de Mexico (Mexico city, Mexico)*

I will present our discovery of a very hot (T $\sim 10^7$ K) circumgalactic medium (CGM) of the Milky Way using a deep *XMM-Newton* observation. It is arguably the hottest component found in the halo of any L* galaxy so far. Interestingly, this gas, coexisting with the warm-hot (T $\sim 10^6$ K) CGM, has a non-solar mixture of Nitrogen, Neon and Oxygen. The multiphase CGM, a huge reservoir of baryons and metals is potentially a key solution to the "missing baryons" and "missing metals" problems. It plays an instrumental role in the evolution of a galaxy by interfacing the pristine inflows and the metal-enriched outflows. However, studying the highly ionized warm-hot CGM has always been challenging because of its faint diffuse signals. Due to the paucity of strong (significantly detectable) metal lines in soft X-ray, Oxygen is used as the primary tracer element. The temperature is calculated using the relative abundance of OVIII and OVII, and the total baryonic and metallic masses are calculated assuming a solar chemical composition. Our results show that I) it is important to include other metals to correctly infer the temperature of the CGM, and II) the assumption of a solar chemistry may affect previous mass estimations of the $>10^6$ K CGM from the observations of Oxygen emission and absorption. This would provide insights on the heating and chemical enrichment of the Milky Way CGM, and provide important inputs to theoretical models of galaxy formation and evolution.

108.02 — Point source contribution to the Diffuse X-ray Background below 1 keV and its effect on our understanding of the circum-galactic medium

Sicong Huang[1]; Massimiliano Galeazzi[1]; Wenhao Liu[3]; Eugenio Ursino[1]; Anjali Gupta[2]

[1] *Department of Physics, University of Miami (Miami, Florida, United States)*

[2] *Columbus State Community College (Columbus, Ohio, United States)*

[3] *University of Alabama (Huntsville, Alabama, United States)*

We studied the spectral signatures of different components of the Diffuse X-ray Background (DXB), including Local Hot Bubble (LHB), Solar Wind Charge eXchange (SWCX), Galactic Halo, and typically unresolved point sources (Galaxies and AGN), in the direction of the Chandra Deep Field South (CDFS) using the 4 Ms XMM-Newton survey and Chandra identified point sources. In this paper we preset our results showing how the different components contribute to the DXB below 1 keV. In particular, we have found that a significant fraction of the emission at ¾ keV, which is typically associated with Galactic Halo (GH) and Circum-galactic medium (CGM) is, in fact, due to emission from typically unresolved Galaxies. We'll discuss the effect that this has on our understanding of GH and CGM, and to our understanding of the missing CGM baryons.

108.03 — Impact of Supernovae-driven Outflows on the Circumgalactic Medium and Its X-ray Properties

Miao Li[1]*; Stephanie Tonnesen*[1]
[1] *Center for Computational Astrophysics, Flatiron Institute (New York City, New York, United States)*

Observationally, most cosmic baryons and a significant amount of metals are missing from galaxies (the "missing baryon problem"). Galactic outflows driven by supernovae (SNe) carry energy, mass, and metals into the circumgalactic medium (CGM), thus understanding the impact of these outflows may lead to a solution of the missing baryon problem. However, simulations, our best tools for tracking unobserved gas, frequently rely on ad hoc feedback models with parameters tuned to match the observations, thus their predictive power for the CGM is severely limited. In this talk, I will show a suite of simulations focusing on the CGM, with outflow fluxes taken from high-resolution simulations of SNe in a multiphase interstellar medium. I will discuss how SNe-driven outflows regulate the CGM, and in particular, how sensitively the CGM properties depend on the outflow parameters. The X-ray luminosity from galactic coronae puts important constraints on the interaction of outflows and pre-existing gas and the mass content of the hot CGM ($T > 10^6$ K). I will compare X-ray properties of the simulated CGM, such as spatial distribution and temperature, to the observations from *Chandra* and *XMM- Newton*. Finally, I will make predictions for future missions, such as *Lynx, Arcus* and *ATHENA*, and discuss how their unprecedented sensitivity and spectral resolution can shed light on the working mechanism of feedback and the missing baryon problem.

108.04 — Charge exchange in the central region of M51

Hang Yang[1,2]*; Shuinai Zhang*[1]*; Li Ji*[1]
[1] *Purple Mountain Observatory (Nanjing, Jiangsu, China)*
[2] *University of Science and Technology of China (Hefei, Anhui, China)*

With XMM-Newton/RGS data, we perform a detailed spectral modeling of the central region of a nearby star-forming galaxy that hosts a low-luminosity AGN, M51, and find the spectrum can be characterized by a thermal plasma plus a charge exchange (CX) component. The temperature of the diffuse hot gas is ∼0.5 keV, with sub-solar metal abundances, except for nitrogen. CX accounts for ∼35% of the total gas emission. The CX is believed to be a result of outflowing hot gas interacting with ambient neutral gas. Both the AGN and stellar activity could be responsible for the outflow, but conclusive disentanglement requires extra efforts. This work implies that CX can be possibly significant in galaxies with AGN-driven outflow.

108.05 — A Consistent Model of Local Interstellar Cosmic-Ray Spectra and Non-Thermal Interstellar Emissions

Elena Orlando[1]
[1] *Stanford University (Stanford, California, United States)*

Cosmic rays produce interstellar emission at gamma-ray energies, seen by Fermi LAT, by interacting with gas and photons in the Galaxy. At the other side of the electromagnetic spectrum, the same cosmic-ray electrons produce interstellar emission at radio and microwaves by spiralling in the Galactic magnetic fields. Accounting for multifrequency observations of the interstellar emission from radio to gamma rays for specific regions, and accounting for the latest accurate cosmic-ray direct measurements, as a first result we obtain a measurement of the local interstellar cosmic-ray spectra independent of solar modulation, and stringent information on propagation models. Then, we use our resulting best model to calculate the expected all- sky gamma-ray emission distribution. As a second result, we find that this best model produces a more peaked inverse-Compton emission in the inner Galaxy region with respect to the standard models used so far in studies of Fermi Large Area Telescope data. This contribution discusses the results based on the work published in Orlando (2018) MNRAS 475, 2724 and Orlando (2019) Physical Review D accepted.

108.06 — Cold gas precipitation in elliptical galaxy atmospheres heated by AGN cosmic rays

Chaoran Wang[1]*; Mateusz Ruszkowski*[1]*; Hsiang-Yi Karen Yang*[2]*; Yuan Li*[3]

[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*
[2] *University of Maryland (College park, Maryland, United States)*
[3] *Center for Computational Astrophysics (New York City, New York, United States)*

Recent observations have found extended multiphase (MP) gas in a significant fraction of massive elliptical galaxies. The presence of MP gas may be crucial for the co-evolution of the central engine and the gaseous halo in these galaxies, especially in the model of precipitation-driven AGN feedback. We perform 3D hydro simulations of two idealized ellipticals: one representing a typical galaxy characterized by initial conditions conducive to the development of thermal instability (TI) and the other one less likely to develop TI. We find that in one class of ellipticals (hereafter SPG), where the entropy of the hot halo gas rises sharply as a function of radius, the hot halo is thermally stable and runaway cooling only happens in the very centers of galaxies. In the other class of ellipticals (hereafter MPG), characterized by shorter cooling times, non-linear perturbation driven by AGN feedback can cause the hot gas to frequently precipitate and form extended MP filaments. Both MPG and SPG experience cooling-driven AGN feedback cycles. However, long- term evolution of both MPG and SPG leads to the formation of massive cold disks that persist over Gyrs. As such disks are not observed in most ellipticals, we suggest that this aspect of the simulations is not physical. One potential solution is to consider cosmic ray (CR) dominated AGN jet feedback. Here we test a hypothesis that CRs diffusing or streaming out of the AGN-inflated cavities could heat the ISM and potentially effectively offset radiative cooling in the outer parts of the atmospheres in the time-averaged sense thus preventing the formation of the long-lived cold disks. Interestingly, recent simulations of a single short-duration jet in the galaxy cluster show that CR-dominated jets could i) efficiently uplift the hot halo (thus could potentially result in the limiting of the formation of the disk in the long term) and ii) make the ISM more prone to the development of TI in the very centers of the atmospheres on short timescales. We present preliminary results of long-term, self-regulated, and CR-heated atmospheres of MPG and SPG to quantify the net amount of precipitation and assess if CR heating can prevent the formation of cold and long-lived disks.

108.07 — Particle acceleration in shocks: from astrophysics to the laboratory in silico

Frederico Fiuza[1]; Anna Grassi[1]; Charles Ruyer[1]
[1] *Department of High Energy Density Science, SLAC National Accelerator Laboratory (Menlo Park, California, United States)*

Astrophysical shocks can be efficient particle accelerators. While diffusive shock acceleration (DSA) is a well-established mechanism, the microphysics underlying magnetic field amplification and particle injection into the DSA phase is not yet fully understood. The combination of first principles plasma simulations and high-energy laser-plasma experiments can play an important role in the exploration of the microphysics of particle acceleration in collisionless shocks. I will present recent results from large-scale fully kinetic simulations and experiments at the OMEGA and NIF facilities that bring novel insights into magnetic field amplification and particle injection in astrophysical shocks [1,2].

References [1] C. M. Huntington, F. Fiuza et al, Nature Physics 11, 173(2015); [2] C. Ruyer and F. Fiuza, Physical Review Letters 120, 245002 (2018)

108.09 — Searching for Faint X-ray Emission from Galactic Stellar Wind Bow Shocks

Breanna Binder[1]; Matthew S. Povich[1]; Patrick Behr[1]; Henry A. Kobulnicky[2]
[1] *Department of Physics & Astronomy, California State Polytechnic University, Pomona (Pomona, California, United States)*
[2] *University of Wyoming (Laramie, Wyoming, United States)*

Stellar wind bow shocks produced by runaway OB stars (M > 8 Msun) are believed to be a major source of high-energy emission in the Milky Way. Faint ($<10^{30}$ erg/s) non-thermal emission is expected to arise from relativistic particles (mainly electrons) being accelerated by a magnetic field at the shock front via first-order Fermi acceleration, but direct X-ray observations from bow shocks at >0.5 kpc from the Sun require prohibitively long exposure times. We have used 2.61 Msec of archival Chandra X-ray observations containing 60 unique infrared bow shocks (selected from the Kobulnicky et al. 2016 catalog and the Milky Way Project DR2 release) to search for faint X-ray emission via stacking analysis. We do not detect significant X-ray emission from the location of the IR bow shocks. This implies an upper limit on the 0.5-7 keV luminosity of the average Galactic stellar wind bow shock of $<3\times 10^{29}$ erg/s. It is likely that the average ISM density and/or the mass loss rates of massive stars are, on average, too low to efficiently produce X-rays coincident with the infrared bow shock.

108.10 — X-ray Intensity and Polarization Probes of Turbulence in Supernova Remnants

Matthew Baring[1]
[1] *Department of Physics and Astronomy, Rice University (Houston, Texas, United States)*

The ability of shocks in the outer shells of supernova remnants (SNRs) to accelerate cosmic rays up to the knee above 1 PeV is strongly dependent on the nature of the turbulence in the shock environs. The paradigm of field enhancement through current-driven instabilities has promoted high levels of turbulence of unexpectedly strong magnetic fields, seeding diffusion near the Bohm limit. The underpinning for a high-field scenario was the detection 15 years ago of "thin rims" of X-ray emission in a handful of young SNRs by Chandra, indicating strong synchrotron cooling. Radio polarization observations corresponding to GeV electrons suggest lower levels of turbulence. With the prospect of spatially-resolved X-ray polarimetry for supernova remnants on the horizon, ushered in by the Imaging X-ray Polarimetry Experiment (IXPE), probes of turbulence using synchrotron signals from 10-100 TeV electrons will soon be possible. This paper explores this prospect, presenting models of X-ray intensity and polarization signatures from prescribed turbulence in SNR shocks, and how these couple to MHD turbulence variances. Higher variances naturally depolarize the signal, and roughly linear and quadratic correlations between standard deviations for the Stokes parameters and the MHD variance emerges. These signatures are explored on both the larger scales of the remnant, and the more confined synchrotron rims. For the rim investigation, spatial profiles of Chandra data from SN 1006 and Cas A are employed to constrain the parameters of turbulence at scales corresponding approximately to the angular resolution.

108.11 — Measuring the Asymmetries of Heavy Elements in Cassiopeia A

Tyler Holland-Ashford[1]*; Laura Lopez*[1]
[1] *Department of Astronomy, The Ohio State University (Columbus, Ohio, United States)*

Evidence has mounted that supernovae (SNe) can have significant deviations from spherical symmetry. Supernova remnants (SNRs) offer the means to study SNe hundreds to thousands of years after explosion, and their properties can be compared to predictions from simulations to probe the mechanism that drives the explosions. In this talk, we will discuss the X-ray morphologies of different elements (from oxygen to iron) found in the youngest core-collapse SNR in the Milky Way, Cassiopeia A. We find that each element has a distinct morphology, which we relate to the burning process that created it, the proximity of its synthesis site from the center of explosion, and the direction of neutron star's motion. Our results provide observational evidence for recent SN simulation predictions: heavier elements show more asymmetric morphologies and are opposed to the direction of neutron star kick velocity.

108.13 — Inferring the Properties of Core Collapse Supernova Progenitors with Machine Learning

Daniel Patnaude[1]*; Herman Lee*[2]
[1] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*
[2] *Kyoto University (Kyoto, Japan)*

There is a clear connection between the evolutionary properties of a massive star and the properties of the resultant supernova and remnant. Here we present new results where we have modeled 45,000 core collapse supernova remnant models to ages of 5000 years, and synthesized spectra for both the shocked circumstellar material and shocked ejecta at 10 epochs across the life of the remnant. Supernovae and their circumstellar environments are asymmetric. To account for this important affect, linear combinations of these spherically symmetric models were used to construct asymmetric models which we then trained a k-nn algorithm on. We then applied these models to Galactic and Magellanic Cloud remnants in order to understand properties of the progenitor systems. In this talk, I will present results from this study, discuss limitations of our approach, and present ideas on how these methods may be used in extragalactic SNR surveys performed with future high resolution X-ray telescopes.

108.14 — Supernova Remnants in Turbulent Medium

Dong Zhang[1,2]*; Roger Chevalier*[2]
[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*
[2] *University of Virginia (Charlottesville, Virginia, United States)*

Core-collapse supernova explosions may occur in the highly inhomogeneous molecular clouds in which their progenitors were born. We perform a series of 3-dimensional hydrodynamic simulations to model the interaction between an individual supernova remnant (SNR) and a turbulent molecular medium, in order to investigate possible observational evidence for the turbulent structure of molecular clouds. We find that the properties of SNRs are mainly controlled by the mean density of the surrounding medium. We compare our simulations to observed SNRs, in particular, to W44, W28 and IC 443. We estimate that the mean density of the ambient medium is ∼10 cm^{-3} for W44 and W28, significantly lower average density than that of the host giant molecular clouds. This result may be related to the stellar feedback from the SNRs' progenitors. We also explore the impact of cosmic rays on the dynamics and momentum feedback of the remnants.

108.15 — Sub-Stellar Lens Populations in Extragalactic Systems

Xinyu Dai[1]; Saloni Bhatiani[1]; Eduardo Guerras[1]
[1] *Department of Physics and Astronomy, University of Oklahoma (Norman, Oklahoma, United States)*

Quasar microlensing serves as a unique probe of the discrete sub-stellar objects in extragalactic lenses such as galaxies and galaxy clusters, first demonstrated in the lens RX J1131-1231. This opens a new discovery space to study free-floating planets or primordial black holes in this mass regime. We further employ this technique on two extragalactic lens systems, one galaxy lens Q J0158–4325 (zs = 1.294, zl = 0.317) and one cluster lens SDSS J1004+4112 (zs = 1.734, zl = 0.68). The Chandra observations of two gravitationally lensed quasars exhibit spectral variability of the FeKα emission that is uncorrelated between the images. These frequently observed structural variations of the emission line can be explained as microlensing effect of the FeKα emission region induced by planet-sized microlenses. To corroborate this, we perform microlensing simulations to determine the probability of a caustic encountering the source region and compare this with the observed line shift rates. We detect the sub-stellar population in QJ0158, with masses ranging from Moon to Jupiter sized bodies and constrain the upper limit of the population in the intracluster light of cluster lens SDSSJ1004. We discuss the implications on the models of free-floating planet and primodial black hole formation theories.

108.16 — AstroSat UV and X-ray Obserations of M31

Denis Leahy[1]
[1] *Department of Physics and Astronomy, University of Calgary (Calgary, Alberta, Canada)*

A survey of M31 is being carried out with the AstroSat Satellite in ultraviolet (UV), soft X-rays, and hard X-rays using the UltraViolet Imaging Telescope (UVIT), Soft X-ray Telescope(SXT), Large Area X-ray Proportional Counter (LAXPC), and Cadmium Zinc Telluride Imager (CZTI) instruments. The survey consists of 19 separate pointings covering M31 with the smallest- instrument-field-of-view, the 28 arcmin diameter field of the UVIT instrument. Most of the data has been observed and is being processed. Initial results from analysis of the central bulge field, identifying a few dozen hot young stars, have appeared in Leahy, Bianchi, Postma 2018, AJ, 156,259). The analysis is extended to include X-ray data here, and includes several new pointings covering the spiral arms of M31.

108.17 — Exploring a Cosmic-Ray Origin of Multiwavelength Emission in M31

Alex McDaniel[1]
[1] *Department of Physics, University of California, Santa Cruz (Santa Cruz, California, United States)*

Recently detected gamma-ray emission in the central region of M31 has led to several possible explanations being put forth, including dark matter annihilation and millisecond pulsars. Another possibility is that the emission in M31 can be accounted for with purely astrophysical cosmic-ray scenario. Relativistic cosmic-ray electrons in the presence of magnetic fields produce radio emission through synchrotron radiation, while X-rays and gamma rays are produced when these electrons upscatter ambient CMB and stellar photons through inverse Compton scattering. Additionally, cosmic-ray proton collisions eventually produce secondary cosmic-ray electrons and gamma-rays through charged and neutral pion decays which can then be detected by their radiative emission, or detected directly in the case of the neutral pion decay gamma rays. In this talk, I will present the prospects for a cosmic-ray explanation for multiwavelength emissions in the central regions of M31, taking into consideration primary cosmic-ray electrons as well as electrons and gamma-rays of hadronic origin.

108.18 — Future constraints on VHE gamma-ray emission from the Fermi Bubbles

Soebur Razzaque[1]; Lili Yang[2,1]
[1] *University of Johannesburg (Auckland Park, South Africa)*
[2] *Sun Yat-Sen University (Zhuhai, China)*

The fermi bubbles (FBs) are two giant gamma-ray lobes above and below the Galactic center. Their origin is not clear yet and can be well explained by both hadronic and leptonic models. In the hadronic model, acceleration of protons and/or nuclei and their subsequent interactions with gas in the bubble volume can produce observed gamma rays and high-energy neutrinos as counterparts. The detection of neutrinos can discriminate between a hadronic and a leptonic origin of FB sufficiently. Recently HAWC reported no gamma ray excess from northern bubble at high latitude, which agrees with Fermi-LAT observations. However, due to a limited sensitivity at low Galactic latitude and high energy threshold at HAWC, the hadronic model is not constrained for the central region of the FB. Here we present the sensitivity study of Cherenkov Telescope Array (CTA) to our FB hadronic model with the morphological analysis and classical on/off analysis based on the expected CTA Galactic Centre and Galactic Plane Survey (GPS). As a complementation and comparison, we study the detectability of FBs with the future ground-based Cherenkov detector LHAASO as well.

108.21 — Most field ultra diffuse galaxies are not failed Milky Way type galaxies

Orsolya Kovacs[1]; *Akos Bogdan*[1]
[1] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

The population of Ultra Diffuse Galaxies (UDGs) was discovered decades ago in the Virgo Cluster. These curious galaxies have stellar masses similar to dwarf galaxies, but their physical size is comparable to the Milky Way. Recent technological advancements in the observations of low surface brightness systems refocused the interest in studying UDGs. The evolutionary path of these galaxies, however, remains ambiguous with two main formation scenarios considered. UDGs may either be failed massive galaxiest or spatially extended dwarf galaxies. A major difference between these scenarios is the halo mass of galaxies. While the former scenario suggest high dark matter fractions, in the latter scenario, UDGs reside in dwarf-size halos. Since the X-ray luminosity of the hot gas is a robust tracer of the dark matter halo mass, we explore the X-ray properties of UDGs. If UDGs reside in massive halos, they should be able to retain a significant amount of hot gas. If, however, UDGs preferentially live in dwarf-size halos, they are not likely to be able to retain any hot gas. To probe the average X-ray emitting properties of UDGs, we combine optical data of previously detected UDGs from the Subaru Telescope, and X-ray data from the XMM-Newton XXL survey. After stacking the counts for each galaxy, we do not detect statistically significant X-ray signal. We compute an upper limit on the luminosity, which is about 2 orders of magnitude lower than that for galaxies with Milky Way mass halos. This suggests that most of the UDGs reside in dwarf-size halos.

108.22 — XMM-Newton Survey of Magellanic Bridge

Ryan Charles Le Roux[1]
[1] *Department of Astronomy, University of Cape Town (Cape Town, Western Cape, South Africa)*

Along with available optical data of the Magellanic Bridge (the interconnecting region between the Small & Large Magellanic Cloud), we aim to characterise the X-ray binary population as a function of the local stellar population (in terms of age, metallicity, and stellar density) in the Bridge. Gardiner & Noguchi (1996) suggests that closest approach between Small & Large Magellanic Cloud, as evidenced by dramatic phase shift in star formation, occurred approximately ~200 Myr ago. During the approach, gas had been tidally stripped (most likely from the Small Magellanic Cloud) into the interconnecting Bridge. According to models of star formation history (Harris 2007), alongside optical surveys of the Bridge, there is strong evidence to suggest that the young, low metallicity stellar population formed in situ, rather than being tidally stripped from either Magellanic Cloud. Studying this region enables for a closer look at galaxy mergers, as well as how this environment (gas density, metallically) affects star formation. Thus the Magellanic Bridge gives us a window into galaxy interaction mechanics, as it contains resolvable X-ray and optical sources. X-ray data is obtained through the XMM-Newton from three separate fields, located near the Western Bridge, which coincides with available optical data. X-ray binary candidates will be followed up with spectroscopic analysis, using the 1.9m telescope located in Sutherland, South Africa.

108.23 — Nearby Galaxy Surveys in the 2020's and Beyond: The Post *Chandra* and *XMM-Newton* Era

Neven Vulic[1,2]; *Ann Hornschemeier*[1,3]; *Joern Wilms*[4]; *Andreas Zezas*[5,7]; *Antara Basu-Zych*[1]; *Thomas Maccarone*[6]; *Andrew Ptak*[1,3]; *Mihoko Yukita*[3,1]
[1] *NASA GSFC (Greenbelt, Maryland, United States)*
[2] *University of Maryland (College Park, Maryland, United States)*
[3] *John Hopkins University (Baltimore, Maryland, United States)*
[4] *University of Erlangen - Nuremberg (Nuremberg, Germany)*
[5] *University of Crete (Crete, Heraklion, Greece)*

[6] Texas Tech University (Lubbock, Texas, United States)
[7] Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)

We present prospects for studying black hole and neutron star populations in nearby galaxies, focusing on science topics that need to be addressed by next generation X-ray telescopes. Important questions that can be answered by next generation X-ray telescopes include: how many of the rare (and potential gravitational-wave progenitor) Wolf-Rayet X-ray binaries exist? What are the population characteristics (e.g., accretion mechanism, age dependence, spin period distribution) of X-ray pulsars and the newly discovered ultraluminous X-ray pulsars? What is the role of supernova kicks in the dynamical evolution of X-ray binaries in different environments? Capabilities such as a large field of view, improved angular resolution, increased sensitivity/effective area, and timing capabilities are required to answer such questions and expand our understanding of X-ray binaries in the Local Universe. We will summarize the prospects for answering these questions based on our current knowledge and simulations of Athena Wide Field Imager observations of galaxies.

108.24 — X-ray Binary Population Constraints in Nearby Galaxies from 20 Years of Chandra Data

Bret Lehmer[1]; Rafael Eufrasio[1]; Antara Basu-Zych[2]; Tassos Fragos[3]; Ann Hornschemeier[4]; Andrea Prestwich[5]; Andrew Ptak[4]; Panayiotis Tzanavaris[4]; Mihoko Yukita[6]; Andreas Zezas[7]
[1] Univ of Arkansas (Fayetteville, Arkansas, United States)
[2] University of Maryland, Baltimore County (Baltimore, Maryland, United States)
[3] Geneva Observatory (Geneva, Switzerland)
[4] NASA GSFC (Greenbelt, Maryland, United States)
[5] CfA (Cambridge, Massachusetts, United States)
[6] Johns Hopkins University (Baltimore, Maryland, United States)
[7] Univ of Crete (Heraklion, Greece)

The recent LIGO/VIRGO detections of gravitational waves (GWs) from merging BHs and NSs have prompted a resurgence in efforts to self-consistently model close binary populations and their evolution. X-ray binaries (XRBs) provide an important benchmark for such efforts, and scaling relations between high-mass XRB (HMXB) and low-mass XRB (LMXB) population demographics and physical properties, like stellar mass (M*), star-formation rate (SFR), metallicity, and stellar age are critical benchmarks for population synthesis models. Thanks to data collected over the last 20 years by Chandra and XMM-Newton, substantial insight has been gained into how the XRB phase is manifested within a variety of galactic environments. We present here new results based on ~7 Ms of archival Chandra data for a sample of 38 nearby galaxies (D = 3.4-29 Mpc), spanning all galactic morphologies, with excellent multiwavelength data (primarily from SINGS). We use new subgalactic analysis techniques to explore how the X-ray luminosity functions (XLFs) of XRBs vary with specific SFR (sSFR = SFR/M*) and self-consistently characterize the HMXB and LMXB contributions to the XLFs of all galaxies. We find that the HMXB and LMXB XLFs exhibit more complex shapes and variations with sSFR than previously reported, and we find evidence for metallicity and stellar age dependences in the XLF shapes and scalings. We put into context these findings with recent studies of XRB evolution reported from the Chandra Deep Fields and COSMOS surveys, and discuss ways forward for linking studies of XRBs to other astrophysical systems (e.g., GW sources).

109 — Missions and Instruments Poster Session

109.01 — Development of a Silicon Tracker for the All-sky Medium Energy Gamma-ray Observatory Prototype

Sean Griffin[1]
[1] UMCP / NASA GSFC (Greenbelt, Maryland, United States)

In this contribution, we present the design for a silicon tracker designed for the All-sky Medium Energy Gamma-ray Observatory (AMEGO) prototype which is currently being developed at the NASA Goddard Space Flight Center and US Naval Research Lab. AMEGO is a Probe-class mission concept which will operate from a few hundred keV to > 10 GeV. The AMEGO tracker comprises sixty layers of double-sided silicon strip detectors (DSSDs). Using DSSDs allows for both the x- and y- coordinates of particle interactions to be measured simultaneously; this is crucial at low energies where Compton scattering is the dominant interaction process. The tracker must also minimize the amount of passive material within the instrument in order to maximize sensitivity, requiring several detectors to be daisy-chained together. This is challenging due to the fact that daisy-chained detectors have high parasitic capacitance which leads to increased readout noise, ultimately limiting the low-energy performance of the instrument. We will discuss the current status of DSSD testing ongoing at NASA Goddard as well as the status of the front-end electronics being developed in preparation for an upcoming beam test and balloon flight.

109.02 — Position-sensitive High-resolution CdZnTe Calorimeter for AMEGO

Elizabeth Hays[1]; Aleksey Bolotnikov[3]; Carolyn Kierans[4]; Alexander MOISEEV[2,5]; David J. Thompson[1]

[1] *NASA GSFC (Greenbelt, Maryland, United States)*

[2] *CRESST, NASA GSFC (Greenbelt, Maryland, United States)*

[3] *Brookhaven National Laboratory (Upton, New York, United States)*

[4] *NPP, NASA GSFC (Greenbelt, Maryland, United States)*

[5] *University of Maryland (College Park, Maryland, United States)*

We will present a concept for a calorimeter based on a novel approach of 3D position-sensitive virtual Frisch-grid CdZnTe (CZT) detectors. This calorimeter aims to measure photons with energies from ~100 keV to 20-50 MeV. The expected energy resolution at 662 keV is better than 1% FWHM, and the photon interaction position-measurement accuracy is better than 1 mm in all 3 dimensions. Each CZT bar is a rectangular prism with typical cross-section of 6x6 mm^2 and length of 2-4 cm. The bars are arranged in modules of 4 × 4 bars, and the modules themselves can be assembled into a larger array. The 3D virtual voxel approach solves a long-standing problem with CZT detectors associated with material imperfections that limit the performance and usefulness of relatively thick detectors (i.e. > 1 cm). Also, it allows us to relax the requirements on the quality of the crystals, while maintaining the same energy resolution and significantly reducing the instrument cost. Such a calorimeter can be successfully used in space telescopes that use Compton scattering of gamma rays, such as AMEGO, serving as part of its calorimeter and providing the position and energy measurement for Compton- scattered photons (like a focal plane detector in a Compton camera). Also, it could provide suitable energy resolution to allow for spectroscopic measurements of gamma-ray lines from nuclear decays.

109.03 — The All Sky Medium Energy Gamma-ray Observatory (AMEGO) - A Discovery Mission for the MeV Band

Elizabeth Hays[1]

[1] *NASA GSFC (Greenbelt, Maryland, United States)*

The MeV domain is one of the most underexplored windows on the Universe. The All-Sky Medium-Energy Gamma-ray Observatory (AMEGO) is a probe concept poised to change that. AMEGO can extend the richly varied observations found by Fermi-LAT in the GeV domain to lower energies and open up currently unobtainable views into the workings of astrophysical jets and the extreme physics of compact objects. At this time, the dawn of the multimessenger era with discoveries of high energy astrophysical neutrinos and direct observations of gravitational waves, a medium-energy gamma-ray surveyor like AMEGO offers unique and essential observations of these extreme environments. In this talk I will present the AMEGO concept and expected performance characteristics along with key examples of science that will be possible.

109.04 — Development of the Anti-Coincidence Detector for the All-sky Medium Energy Gamma-ray Observatory

Alyson Joens[1]

[1] *George Washington University (District of Columbia, Washington, United States)*

The MeV sky is filled with rich scientific potential which has previously been under explored due to the challenge of observing both Compton scattering and pair production events within this regime. The All-sky Medium Energy Gamma-ray Observatory (AMEGO) is a proposed probe-class mission concept designed to operate between .2 MeV to 10 GeV and is intended to deepen our knowledge of the MeV energy band. AMEGO will be comprised of four hardware subsystems: the cadmium zinc telluride (CZT) calorimeter, cesium iodide (CsI) calorimeter, anti-coincidence detector (ACD), and the double sided silicon strip tracker (DSSD). The ACD is a plastic scintillator detector read out by silicon photomultipliers (SiPMs) and provides charged particle background rejection. In the development of the ACD many factors must be taken into account in order to optimize the detector's charged particle detection efficiency. One such factor is the determination of whether wave-length shifter (WLS) bars provide a better detector readout. To determine this, SiPMs will be both directly coupled to the scintillating material as well as to WLS bars and detection efficiency will be measured. This contribution will discuss the development of the ACD as well as detail the results obtained.

109.05 — Diffuse gamma-ray line astronomy with AMEGO

Carolyn Kierans[1]; Andreas Zoglauer[2]; Chris L. Fryer[3]; Dieter Hartmann[5]; Chris Shrader[4]

[1] NASA/GSFC (Washington, District of Columbia, United States)
[2] UC Berkeley/Space Sciences Lab (Berkeley, California, United States)
[3] Los Alamos National Lab (Los Alamos, New Mexico, United States)
[4] Catholic University of America (Washington, District of Columbia, United States)
[5] Clemson University (Clemson, South Carolina, United States)

Gamma-ray line astronomy began in the 1970s, but the field is still in its infancy due to limitations in current telescope technologies. The signature of positron annihilation at 511 keV was the first gamma-ray emission line to be detected as originating outside of our solar system. After 40 years of observations, the Galactic sources of positrons, which annihilate predominately in the Galactic Center region, are still unconfirmed and remains one of the pioneering topics in gamma-ray astronomy. The next Galactic gamma- ray line to be detected was the 1.8 MeV diffuse emission from the radioactive decay of Al-26, which was the first confirmation of active nucleosynthesis in our Galaxy. Nuclear emission lines from isotopes created in massive stars and their supernovae, such as Fe-60 and Ti-44, in addition to Al-26, allow for fingerprint-like probes into stellar structure and evolution, a tool which has yet to be fully realized. The All-sky Medium Energy Gamma-ray Observatory (AMEGO), is an Astrophysics Probe concept design that can make significant progress in our understanding of cosmic nucleosynthesis and the source of Galactic positrons. AMEGO will have a wide field-of-view, direct imaging capabilities, high spectral resolution, and sensitivity orders of magnitude better than previous telescopes: all characteristics necessary to advance gamma-ray astronomy. In this presentation we will focus on the topics that can be addressed with long-lived stellar nucleosynthesis products and discuss the intriguing open questions associated with Galactic positrons. We will present predictions for AMEGO performance and expected results.

109.06 — Neutrino Astrophysics and AMEGO

Roopesh Ojha[1]; Michael Kreter[2]; Haocheng Zhang[3]; Matthias Kadler[4]; Naoko Kurahashi Neilson[5]
[1] NASA/GSFC/UMBC (Rockville, Maryland, United States)
[2] North West University (Potchefstroom, North West Province, South Africa)
[3] Purdue University (West Lafayette, Indiana, United States)
[4] University of Wuerzburg (Wuerzburg, Bavaria, Germany)
[5] Drexel University (Philadelphia, Pennsylvania, United States)

The possible association of the blazar TXS 0506+056 with a PeV neutrino detected by IceCube holds the tantalizing potential to answer three astrophysical questions: the sites where Cosmic Rays are produced and accelerated, the origins of PeV neutrinos, and the physical mechanisms producing the high energy gamma-ray emission from blazars. AMEGO is the perfect instrument to look for neutrino counterparts because MeV gamma-rays are an excellent proxy for neutrino emission if photo-hadronic processes play a dominant role. Hadronic models also predict a high level of polarization in the MeV band. In addition, AMEGO's wide field of view and sensitivity guarantee it a central role in neutrino astrophysics. We will elaborate on AMEGO's capabilities in the context of multi-messenger astronomy.

109.07 — Cosmic Rays and the Interstellar Medium with the AMEGO Mission

Elena Orlando[1]; Isabelle Grenier[2]; Vincent Tatischeff[2]; Andrei M. Bykov[3]; Jurgen Kiener[2]
[1] Stanford University (Stanford, California, United States)
[2] Laboratoire AIM Paris-Saclay, CEA/IRFU, CNRS, Université Paris Diderot (Gif-sur-Yvette cedex, 91191, France)
[3] Ioffe Institute (Saint-Petersburg, 194021, Russian Federation)

We identify the scientific prospects for studying low-energy cosmic rays, the interstellar medium, and the associated gamma-ray emissions with a next- generation wide-field telescope from 200 keV to ~10 GeV. With improved angular resolution and more than a order of magnitude better sensitivity than previous instruments, the All-sky Medium Energy Gamma-ray Observatory (AMEGO) would allow for the first time to study in detail the low-energy cosmic rays, which play a fundamental role in the formation of stars and in the dynamics of the interstellar medium. It would allow to map the cosmic-ray distribution in order to understand their propagation in the Galaxy. We discuss the importance of having such a telescope, and we present the predictions for the gamma-ray continuum both at large scale and in individual clouds, and for de-excitation nuclear lines.

109.08 — The physics and astrophysics of X-ray outflows from Athena Observations of Active Galactic Nuclei

Sibasish Laha[1]
[1] Centre for Astronomy and Space science, University of California, San Diego (San Diego, California, United States)

TBD

109.09 — Athena to probe the cosmic evolution of supermassive black holes with spectral-timing analysis of tidal disruption flares

Dheeraj Ranga Reddy Pasham[1]
[1] *Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (MIT) (Cambridge, Massachusetts, United States)*

TBD

109.10 — Probing Macro-Scale Gas Motions and Turbulence in Galaxy Cluster Outskirts

Esra Bulbul[1]
[1] *High Energy Astrophysics Division, Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

TBD

109.11 — Progress in the development of microcalorimeter arrays for the Athena X-IFU

Simon Bandler[1]
[1] *X-ray Astrophysics Laboratory, NASA/GSFC (Greenbelt, Maryland, United States)*

TBD

109.12 — Cluster gas dynamics in the epoch of mircocalorimeter

Yuanyuan Su[1]
[1] *University of Kentucky (Lexington, Kentucky, United States)*

TBD

109.13 — Accretion in Stellar-Mass Black Holes at High X-ray Spectral Resolution

Jon Miller[1]
[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

Accretion disks around stellar-mass black holes offer unique opportunities to study the fundamental physics of standard thin disks, super-Eddington disks, and structure that may be connected to flux variability. These local analogues of active galactic nuclei (AGN) are particularly attractive for their proximity, high flux, and peak emissivity in the X-ray band. X-ray calorimeter spectrometers, with energy resolutions of 2-5 eV, are ideally suited to study accretion in stellar-mass black holes. The results will make strong tests of seminal disk theory that applies in a broad range of circumstances, help to drive new numerical simulations, and will inform our understanding of AGN fueling, evolution, and feedback.

109.14 — High Energy Expolanet Science Beyond the Next Decade

Scott Wolk[1]
[1] *High energy, Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

TBD

109.15 — Laboratory Astrophysics Needs for Athena

Randall Smith[1]
[1] *HEAD, Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

TBD

109.16 — Validating the Athena Calibration Requirements

Laura Brenneman[1]*; Lorenzo Natalucci*[2]*; Matteo Guainazzi*[3]*; Esra Bulbul*[1]*; Victoria Grinberg*[4]*; Jos de Bruijne*[3]*; Mariateresa Fiocchi*[2]
[1] *Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*
[2] *INAF (Rome, Italy)*
[3] *ESA (Leiden, Netherlands)*
[4] *University of Tübingen (Tübingen, Germany)*

A critical element of mission success is the ability to accurately calibrate its instrumentation. In preparation for the ∼2030 launch of ESA's Athena X-ray observatory, we are conducting an empirical exercise to verify the consistency between Athena's nominal science objectives and its science and calibration requirements. Our work consists of performing simulations to reproduce the expected measurements obtained through an Athena observation as well as its instrument and telescope performance. More specifically, this validation process is divided into two "tiers," where Tier 1 represents top- level scientific validation of the requirements on the basis of astrophysically-motivated simulations reproducing the corresponding requirements, while Tier 2 derives the systematic uncertainties on the instrument/telescope calibration parameters based on a system-level validation of these requirements using instrument/telescope simulators. Here we describe our progress in this exercise.

109.17 — Reducing Particle Background of X-ray Silicon Based Detectors Through Correlation Analysis

Esra Bulbul[1]*; Ralph Kraft*[1]*; Paul Nulsen*[1]*; Eric D. Miller*[2]*; Catherine E. Grant*[2]*; Marshall Bautz*[2]*; Michael*

Freyberg[3]; Norbert Meidinger[3]; Arne Rau[3]; David Burrows[4]; Steven Allen[5]
[1] *High Energy Astrophysics Division, Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*
[2] *MIT (Cambridge, Massachusetts, United States)*
[3] *Max Planck Institute for Extraterrestrial Physics (Garching, Germany)*
[4] *Penn State University (University Park, Pennsylvania, United States)*
[5] *Stanford University (Stanford, California, United States)*

The main component of the particle-induced instrumental background is secondary electrons and photons generated by high energy cosmic ray protons (with E>100 MeV) depositing some of their energy as they pass through the detector. The detected secondaries of the unfocused component can mimic X-ray events from celestial sources, and they dominate the particle-induced background level. Understanding and further reducing the instrumental background level of future X-ray silicon based detectors (e.g. Athena WFI) would ensure the primary science goals are satisfied with increased margins on exposure and statistical precision. We will present the spatial and energy distribution of valid and rejected events we find in the XMM-Newton filter-wheel-closed data taken in the Small Window Mode. These results will be used to develop an algorithm to reduce the Athena WFI's background on board in the Science Products Module.

109.18 — Signatures of orbital motion in strongly curved space-time of accreting black holes via the upcoming X-ray missions

Vladimir Karas[1]; Katerina Goluchova[2]; Gabriel Torok[2]; Adam Hofer[2]; Eva Sramkova[2]; Pavel Bakala[2]; Karol Petrik[2]
[1] *Astronomical Institute (Prague, Czechia)*
[2] *Institute of Physics, Silesian University (Opava, Czechia)*

We explore the appearance of an observable signal generated by extended accretion tori with a contribution from localized radiating hot spots moving along quasi-elliptic trajectories near the innermost stable circular orbit (ISCO) in the Schwarzschild spacetime. Our on-going effort is aimed to compare the capabilities of observatories operating during the past two decades (represented by the Rossi X-ray Timing Explorer, RXTE) versus two future instruments – Advanced Telescope for High-Energy Astrophysics (Athena) and The enhanced X-ray Timing and Polarimetry mission (eXTP). We conclude that the spectral and timing abilities of the proposed observatories can greatly help to distinguish between the different physical models, significantly beyond the current state of the art.

109.19 — Reducing the Athena WFI Background with the Science Products Module: Results from Geant4 Simulations

Eric D. Miller[1]; Catherine E. Grant[1]; Marshall Bautz[1]; Jonathan Keelan[2]; David Hall[2]; Andrew Holland[2]; Esra Bulbul[3]; Ralph P. Kraft[3]; Paul Nulsen[3]; David Burrows[4]; Steven Allen[5]
[1] *Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*
[2] *Open University (Milton Keynes, United Kingdom)*
[3] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*
[4] *The Pennsylvania State University (University Park, Pennsylvania, United States)*
[5] *Stanford University (Stanford, California, United States)*

The Wide Field Imager (WFI) on ESA's Athena X-ray observatory will include the Science Products Module, hardware that can perform special processing on the science data stream. Our goal is to identify on-board processing algorithms that can reduce WFI charged particle background and improve knowledge of the background to reduce systematics. Telemetry limitations require discarding most pixels on-board, keeping just candidate X-ray events, but information in the discarded data may be helpful in identifying background events masquerading as X-ray events. We present an analysis of Geant4 simulations of cosmic ray protons interacting with the structures aboard Athena, producing signal in the WFI from a variety of secondary particles with various types of particle tracks. We search for phenomenological correlations between these particle tracks and detected events that would otherwise be categorized as X-rays, and explore ways to exploit these correlations with efficient algorithms to flag or reject such events on-board. In addition to possibly reducing the Athena instrumental background, these results are applicable to understanding the particle component in any X-ray silicon-based detector in space.

We gratefully acknowledge support from NASA grant NNX17AB07G, administered by Penn State, and from NASA contracts NAS 8-37716 and NAS 8-38252.

109.20 — Laboratory Measurements in Support of High Energy Astrophysics Orbiting Observatories

Gregory Brown[1]
[1] *Lawrence Livermore National Laboratory (Livermore, California, United States)*

Using the Lawrence Livermore National Laboratory's electron beam ion traps EBIT-I and SuperEBIT coupled with the NASA/GSFC EBIT Calorimeter Spectrometer (ECS) as well as a variety of high resolution crystal and grating spectrometers we have measured the X-ray emission from a variety of astrophysically relavant highly charged ions. Examples of our measurements include collisional excitation cross sections, transition wavelengths, x-ray emission following charge exchange, and dielectronic recombination and resonance excitation resonance strengths. In addition, benchmarks of novel density and temperature diagnostics and diagnostics of magnetic field strength have been completed. Recently, we have also begun systematic studies of ionizing and recombining plasmas using the same system used to simulate plasmas in Maxwellian equilibrium. These measurements are critical for interpreting high resolution x-ray spectra measured using, for example, XRISM and ATHENA. Samples of our recent work will be presented.

Part of this work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and is also supported by NASA grants to LLNL, NASA/GSFC, and Columbia University.

109.21 — The XMM Quiescent Particle Background Spectrum Depends on the Spacecraft Location

K. D. Kuntz[1]; Steve L. Snowden[2]

[1] *Department of Physics & Astronomy, Johns Hopkins University (Baltimore, Maryland, United States)*

[2] *Goddard Space Flight Center (emeritus) (Greenbelt, Maryland, United States)*

Measuring and modeling the quiescent particle background (QPB) spectrum is necessary for analyzing emission that fills the field of view (FOV), such as the emission from the diffuse hot ISM, the Warm-Hot Intergalactic Medium, and clusters of galaxies. The current XMM Extended Source Analysis Software (ESAS) assumes that the QPB spectrum varies with time and builds a background spectrum based upon the hardness ratio measured over pixels outside the FOV. Our new work focusses on the source of the spectral variation. We find that the bulk of that variation is due to the location of the spacecraft with respect to the particle belts extending al the way to the magnetopause. There is negligible variation with the strength of the QPB rate, and small variation with the epoch of the observation. The next generation of ESAS will include these results.

109.22 — The LLNL warm electron beam ion trap (WEBIT): An instrument for ground calibration of space-borne X-ray spectrometers

Tom Lockard[1]; E.W. Magee[1]; Peter Beiersdorfer[1]; Greg V. Brown[1]; Renata Cumbee[2,4]; Megan Eckart[1]; Natalie Hell[1]; Yoshitaka Ishisaki[3]; Richard Kelley[2]; Caroline A. Kilbourne[2]; Maurice A. Leutenegger[2]; F. Scott Porter[2]; Makoto Sawada[2,5]; Shinya Yamada[3]; tomomi watanabe[2,6]

[1] *Lawrence Livermore National Laboratory (Livermore, California, United States)*

[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

[3] *Tokyo Metropolitan University (Tokyo, Japan)*

[4] *NASA Postdoctoral Program (NPP) Fellow (Greenbelt, Maryland, United States)*

[5] *CRESST/UMBC (Baltimore, Maryland, United States)*

[6] *Adnet Systems Inc. (Bethesda, Maryland, United States)*

We have developed a relatively small, portable, warm electron beam ion trap, known as WEBIT, for use as an X-ray calibration source for XRISM's Resolve microcalorimeter spectrometer. WEBIT, originally built in the early 1990s, has a water-cooled magnet with a field strength of approximately 0.5 Tesla, in contrast to the $\sim$ 3 Tesla field produced by the cryogenically cooled EBIT-I and SuperEBIT. WEBIT has successfully been used at the NASA/Goddard Space Flight Center to calibrate the Resolve detector system. Although the charge balance achieved by WEBIT is not as pure as found in EBIT-I or SuperEBIT, x-ray emission from helium-like an hydrogenic ions of low-Z elements have been measured. The X-ray emission from WEBIT has mainly been used to benchmark Resolve's low energy gain calibration and line shape. This device adds versatility to the more common calibration methods based on emission from, for example, characteristic Kα lines produced by X-ray tubes, fluoresced metals, or radioactive sources, and provides well-characterized lines below 1 keV. WEBIT will be used next to calibrate Resolve at a higher level of assembly, following the integration of the detector system with the flight adiabatic demagnetization refrigerator (ADR) in the summer of 2019.

109.23 — IACHEC: The Status of High Energy Cross-Calibration.

Kristin Madsen[1]; Cathrine Grant[3]; Matteo Guainazzi[4]; Vinay Kashyap[5]; Herman Marshall[3]; Eric Miller[3]; Lorenzo Natalucci[2]; Jukka Nevalainen[6]; Paul Plucinsky[5]; Yukikatsu Terada[7]

[1] *SRL, Caltech (Glendale, California, United States)*

[2] *IAPS-INAF (Rome, Italy)*

[3] Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)
[4] ESA-ESTEC (Noordwijk, Netherlands)
[5] Harvard Smithsonian Center for Astrophysics, (Cambridge, Massachusetts, United States)
[6] University of Tartu (Tartu, Estonia)
[7] University of Saitama (Saitama, Japan)

The International astronomical Consortium for High Energy Calibration (IACHEC) was founded in 2006 and has since annually been hosting a workshop attended by instrument teams from all High Energy observatories. Consequently, the IACHEC has become the leading forum on observatory cross-calibration with yearly campaigns, the product of which has been several papers to serve the community. In addition, the IACHEC strives to research and promote best practices in analysis of X-ray data. In this presentation I will summarize the current status of our cross-calibration understanding between on-orbit High Energy observatories, discussing the calibration standards, and report on the statistical work that has been done to improve data analysis.

109.24 — VO standards for multi-mission coordinatinated observations

Celia Sanchez-Fernandez[1]; Erik Kuulkers[1]; Aitor Ibarra[1]; Jesus Salgado[1]; Emilio Salazar[1]; Jan-Uwe Ness[1]; Richard Saxton[1]; Carlos Gabriel[1]; Peter Kretschmar[1]; Matthias Ehle[1]
[1] European Space Agency (Villanueva de la Cañada, Madrid, Spain)

Coordinated multi-wavelength observations are essential to understand the physics governing most of the observable astronomical processes. The demand of such observations by the astronomical community is continuously increasing, specially with the advent of multi-messenger astronomy. In response to this demand, it is expected that the iterations between the various observatories will increase in complexity in the near future. We propose international standards, certified by VO, for observatories to provide their visibility and scheduling information. These will allow the use of automated processes in the observation coordination tasks. Public automated access to visibility and past/present/future observations will allow a number of additional activities. In this talk, we will describe the proposed VO standards and provide examples of use cases.

109.25 — High precision calibration of interstellar oxygen absorption

Jakob R. Stierhof[1,2]; Maurice A. Leutenegger[3,4]; Steffen Kühn[5]; Peter Micke[5,6]; René Steinbrügge[7]; Chintan Shah[5]; Natalie Hell[8]; Matthias Bissinger[1]; Maria Hisch[1,2]; Ralf Ballhausen[1,2]; Melanie Lang[1,2]; Christina Gräfe[1,2]; Severin Wipf[9]; Renata Cumbee[3]; Gabriele Betancourt-Martinez[10]; Sungnam Park[11]; Vladimir Yerokhin[12]; Andrey Surzhykov[6,13]; Moses Chung[11]; Joern Wilms[1,2]; Greg V. Brown[8]; José Crespo López-Urrutia[5]; Sven Bernitt[5,9]
[1] Friedrich-Alexander Universität Erlangen-Nürnberg (Erlangen, Bavaria, Germany)
[2] Institute de Recherche en Astrophysique et Planétologie (Toulouse, France)
[3] Ulsan National Institute of Science and Technology (Ulsan, Korea (the Republic of))
[4] Peter the Great St. Petersburg Polytechnic University (St. Petersburg, Russian Federation)
[5] Technische Universität Braunschweig (Braunschweig, Germany)
[6] Dr. Karl-Remeis Observatory (Erlangen, Bavaria, Germany)
[7] NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)
[8] CRESST/Univ. of Maryland Baltimor County (Baltimore, Maryland, United States)
[9] Max Planck Institut für Kernphysik (Heidelberg, Germany)
[10] Physikalisch-Technische Bundesanstalt (Braunschweig, Germany)
[11] Deutsches Elektronen Synchrotron (Hamburg, Germany)
[12] Lawrence Livermore National Laboratory (Livermore, California, United States)
[13] Friedrich-Schiller Universität Jena (Jena, Germany)

Throughout the universe baryonic matter often manifests as diffuse gas clouds. When backlit by a bright X-ray source, the constituents of the clouds can be identified via absorption lines from atomic inner-shell transitions. Thus, observations in the soft X-ray band allow us to characterize the physical properties of these clouds. By measuring the transition energy we can determine absolute radial velocities. The uncertainty of the velocity is often limited by the accuracy of the rest wavelength or the wavelength calibration. The strong 1s-2p resonance absorption line in atomic oxygen is a suitable candidate for this. Observations of the Galactic Interstellar Medium (ISM) performed with the *Chandra* High Energy Transmission Grating yield a radial velocity with a precision up to 13 km/s (Gatuzz et al. 2013, ApJ). Comparing the measured radial velocities averaged over different lines of sight with laboratory values leads to the unexpected conclusion that the gas has a mean relative velocity of about 340 km/s (Gorczyca et al. 2013, ApJ). This velocity is much larger than the uncertainties resulting from the best existing calibrations, which are based on inner-shell transitions in molecular O_2, and which correspond to ±60-120 km/s (Wight & Brion 1974, JESRP; Hitchcock & Brion 1980, JESRP; Stolte et al. 1997, JPhB; McLaughlin et al. 2013, ApJL; Bizau et al. 2015, PhRvA). Here we present a high resolution measurement of the K-shell transitions of molecular O_2 using a novel calibration method. Measurements of the resonantly excited fluorescence of the well known 1s-*n*p transitions in the He-like ions O^{6+} and N^{5+} produced in an electron beam ion trap (Micke et al. 2018, AIP) are suitable to precisely calibrate the experimental energy scale. Together with simultaneous measurements of the molecular oxygen resonances it is possible to determine the resonance energies with a precision corresponding to ±5 km/s. More strikingly, interpreting the grating spectra from *Chandra* based on the new calibration, we find the averaged radial velocity measurements consistent with zero, as expected.

109.26 — Statistical tools for analysis and modeling of astronomical time series and populations: TSE and CUDAHM

Thomas Loredo[1]; Jeffrey Scargle[2]; Tamás Budavári[3]
[1] *Cornell Center for Astrophysics and Planetary Science, Cornell University (Ithaca, New York, United States)*
[2] *NASA Ames Research Center (Mountain View, California, United States)*
[3] *Johns Hopkins University (Baltimore, Maryland, United States)*

This poster provides an overview of open-source software packages addressing two challenging classes of astrostatistics problems arising in high-energy astrophysics. (1) Time Series Explorer (TSE) is a collection of software in Python and MATLAB for exploratory analysis and statistical modeling of astronomical time series. It comprises a library of stand-alone functions and classes, as well as an environment for interactive exploration of times series data. We summarize key capabilities of this emerging project, including new algorithms for analysis of irregularly-sampled time series. (2) CUDAHM is a C++ framework for hierarchical Bayesian modeling of cosmic populations, leveraging graphics processing units (GPUs) to enable applying this computationally challenging paradigm to large datasets. CUDAHM is motivated by measurement error problems in astronomy, where density estimation and linear and nonlinear regression must be addressed for populations of thousands to millions of objects whose features are measured with possibly complex uncertainties, potentially including selection effects. An example calculation demonstrates accurate GPU-accelerated luminosity function estimation for simulated populations of one million objects in about two hours using a single NVIDIA Tesla K40c GPU.

109.27 — Twenty years of the Advanced CCD Imaging Spectrometer on the Chandra X-ray Observatory

Catherine E. Grant[1]
[1] *Kavli Institute for Astrophysics and Space Research, MIT (Cambridge, Massachusetts, United States)*

As the Advanced CCD Imaging Spectrometer (ACIS) on the Chandra X-ray Observatory enters its twentieth year of operation on orbit, it continues to perform well and produce spectacular scientific results. The response of ACIS has evolved over the lifetime of the observatory due to radiation damage, molecular contamination and aging of the spacecraft in general. Here we present highlights from the instrument team's monitoring program and our expectations for the future of ACIS. Performance changes on ACIS continue to be manageable, and do not indicate any limitations on ACIS lifetime.

109.29 — The weirdest objects in the Chandra Source Catalog 2.

Juan Martinez Galarza[1]; Raffaele D'Abrusco[1]; Francesca Civano[1]; Ian Evans[1]
[1] *Chandra X-ray Center, Center for Astrophysics | Harvard & Smithsonian (Somerville, Massachusetts, United States)*

The version 2.0 of the Chandra Source Catalog (CSC2) offers an unprecedented opportunity for serendipitous discovery. A large number of the detected sources have never been studied before, as they were not the specific target of any observation, but the catalog team has detected them and characterized them at a great level of detail in terms of their X-ray fluxes, hardness ratios, variability, and spectral properties. Among those newly detected sources there will certainly be many objects of known class, such as QSOs, X-ray binaries, young stellar objects, etc. But more interestingly, the catalog very likely contains new types of X-ray sources, and/or known types of X-ray sources observed in rare or unknown states. One possible way to identify these sources is by recognizing that they are likely to behave as outliers with respect to the distribution of properties of all the other sources. If we are indeed able to identify these astrophysical outliers, and provided that they have optical counterparts, they would be natural targets for spectroscopic follow up studies with SDSS-V, as they represent a new ground for discovery. We present state-of-the-art outlier detection algorithms based on machine-learning methodologies that allow us to find the weirdest and therefore most interesting sources in the CSC2. We show initial promising results of applying these algorithms to the CSC2, using only a fraction of the total number of CSC sources and and a limited number of X-ray properties. We have identified objects with remarkable hardness ratios, fluxes, and variability properties, that stick out from the bulk of the sources, and that include both galactic and extragalactic objects. Once the entirety of the catalog and all of the X-ray properties are included in the analysis, we expect to find even more extreme X-ray sources suitable for follow up with upcoming spectroscopic surveys in other wavelength regimes.

109.30 — Chandra X-ray Observatory Optical Axis and Aimpoint

Ping Zhao[1]
[1] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

This year (2019) NASA's Chandra X-ray Observatory will celebrate its 20th anniversary of very successful scientific exploration of the high energy universe. Chandra revolutionized the X-ray astronomy as being the first, and so far the only, X-ray telescope achieving sub-arcsecond spacial resolution. Chandra is comprised of three principal elements: the High Resolution Mirror Assembly (HRMA), Pointing Control and Aspect Determination (PCAD) system, and the Science Instrument Module (SIM), which is where the X-ray detectors mounted and is connected to the HRMA by a 10-meter long Optical Bench Assembly. To achieve and retain the unprecedented imaging quality, it is critical that these three principal elements to stay rigid and stable for the entire life time of the Chandra operation. I will review Chandra's optical Axis, aimpoint, pointing stability, and their impacts to the Chandra operation, and evaluate the integrity and stability of the telescope. I will also review the impact due to the Chandra safemode from October, 2018.

109.31 — Results from the second DXL flight: LHB and SWCX emission at 1/4 keV and the Sun's velocity pointing vector

Dhaka Sapkota[1]
[1] *Department of Physics, University of Miami (South Miami, Florida, United States)*

"Diffused X-ray emission from the Local galaxy" (DXL) is a series of sounding rocket missions to study the Solar Wind Charge Exchange (SWCX) and Local Hot Bubble (LHB) X-ray emissions which are believed to be major contributors to the diffused X-ray background (DXB). DXL-2, launched in December 2015, used four large area proportional counters carrying three unique (carbon, boron, and beryllium based) filters. It scanned through the Helium Focusing Cone (HFC) in two perpendicular directions to separate the LHB and SWCX contribution and to identify the pointing direction of the Sun's velocity vector. Observed contribution from LHB and SWCX at all bands, including B and Be, and the analysis of the solar pointing vector will be presented.

109.32 — The Third Fermi Pulsar Catalog

Brent Limyansky[1,2]
[1] *Department of Physics, University of California, Santa Cruz (Santa Cruz, California, United States)*
[2] *Santa Cruz Institute for Particle Physics (Santa Cruz, California, United States)*

With the number of pulsars detected by the Fermi Large Area Telescope (LAT) now reaching 234, the LAT Collaboration is in the process of compiling its Third Pulsar Catalog (3PC). This builds on the 117 gamma-ray pulsars in 2PC, published in October 2013, and benefits from updated spectral and background models being prepared for the Fourth Fermi LAT Source Catalog (4FGL). In addition to an increase in the number of pulsars, the 3PC also includes novel pulsars, such as the first radio-quiet millisecond pulsar and first extra- Galactic gamma-ray pulsar. Throughout its first decade of operation, the Fermi LAT has proven to be an indispensable tool in the hunt for new and interesting pulsars and shows no signs of slowing down in years to come.

109.33 — The Fourth Fermi LAT Source Catalog (4FGL)

David John Thompson[1]
[1] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The fourth Fermi Large Area Telescope gamma-ray source catalog (4FGL) is nearly complete. Based on the first eight years of science data from the Fermi Gamma-ray Space Telescope mission covering the whole sky in the 50 MeV–1 TeV energy range, it is the deepest yet in this energy band. Relative to the 3FGL catalog, the 4FGL catalog has twice as much exposure as well as a number of analysis improvements, including an updated model for Galactic diffuse gamma- ray emission. The 4FGL catalog includes more than 5000 sources with at least 4σ significance. Seventy-five sources are modeled explicitly as spatially extended. Overall about 2/3 of the sources are associated with known gamma-ray-emitting objects, and many are firmly identified based on angular extent or correlated variability (periodic or flaring) observed at other wavelengths. For the remaining sources we have not found plausible counterparts at other wavelengths. Most of the identified or associated sources are active galaxies of the blazar class, with pulsars being the second largest class.

109.35 — Overview of the prototype 9.7m Schwarzschild-Couder telescope, a pathfinder medium-sized telescope for Cherenkov Telescope Array (CTA)

Reshmi Mukherjee[1]
[1] *Department of Physics & Astronomy, Barnard College, Columbia University (New York, New York, United States)*

A prototype Schwarzschild-Couder Telescope (pSCT), using a 9.7 m diameter primary mirror, has been built at the Fred Lawrence Whipple Observatory in southern Arizona. The pSCT is a candidate pathfinder for the Medium Size Telescopes (MSTs) of the Cherenkov Telescope Array (CTA). The SCT employs an aplanatic two-mirror optical system to simultaneously increase the field of view and significantly improve the imaging resolution using a compact high- resolution camera. The SCT-MST operates using the atmospheric Cherenkov technique and is expected to be sensitive to gamma rays in the energy range from a several tens of GeV to a few tens of TeV. The pSCT, inaugurated in January 2019, has the full mechanical and optical systems, but partially instrumented camera, has been in development since 2012, with construction starting in early 2016. Plans are now underway to instrument the compact SCT camera to the full 8-degree FoV with more than 11,000 SiPM channels. The two- mirror design of the SCT is expected to dramatically improve the optical imaging of the atmospheric Cherenkov cascades so as to permit the enhancement of the gamma-ray angular resolution and particularly off-axis sensitivity. The dual-mirror design makes the SCT attractive for the sky survey, the study of extended gamma-ray sources and follow up observations of transients in the context of multi-wavelength and multi-messenger astrophysics. In this presentation we will give an overview the current status of the pSCT project.

109.36 — Relativistic Image Doubling in Astronomical Cherenkov Detectors and Telescopes

Robert Nemiroff[1]
[1] *Department of Physics, Michigan Technological University (Houghton, Michigan, United States)*

A novel type of apparent relativistic kinematics may soon become detectable in Earth-based astronomical Cherenkov detectors and telescopes. For detectors, when a charged particle moving near the speed of light in vacuum enters a dense medium such as water, it not only creates Cherenkov light, but two diverging Cherenkov-emitting "images" of the particle. The two images will suddenly appear along the path of the particle, an event usually identified with a Cherenkov Ring. One particle image will subsequently proceed along the direction of motion of the particle, while the other image will appear to move backwards along the earlier path of motion. Capturing evidence of both Cherenkov-emitting images has not yet been done, to the best of the author's knowledge, but should be possible. Perceived pair events and image-doubled trajectories carry information about the charged particle's direction and deceleration beyond that of recording the time and location of a Cerenkov Ring. Astrophysics-oriented observatories that monitor tanks and basins of water for Cherenkov radiation and might be adaptable to detecting relativistic and superluminal image doubling include HAWC and IceCube. Similarly, for Cherenkov telescopes, an air shower emitting Cherenkov light might be time resolved to show the air shower moving backwards along its track, or start with two images which then appear to move in opposite directions along the track. Telescopes that might see such image doubling include H.E.S.S. and CTA.

109.37 — The Cherenkov Telescope Array near Birth: The Future of Very-High-Energy Gamma-Ray Astrophysics

David A. Williams[1]
[1] *University of California, Santa Cruz (Santa Cruz, California, United States)*

The Cherenkov Telescope Array (CTA) will be a new observatory for the study of very-high-energy (VHE) gamma-ray sources, designed to study energies from 20 GeV to 300 TeV with sensitivity improved by a factor of 5 to 20, depending on the energy, compared to currently operating instruments: VERITAS, MAGIC, and H.E.S.S. CTA will probe known sources with unprecedented sensitivity, angular resolution, and spectral coverage, while also detecting hundreds of new sources. CTA will provide observing opportunities in this energy band to members of the wider astronomical community for the first time. The CTA Consortium will also conduct a number of Key Science Projects, including a Galactic Plane survey and a survey of one quarter of the extragalactic sky, creating legacy data sets that will also be available to the public. This presentation will highlight the role of CTA in the broader context of current and future high-energy missions and in particular the central role of VHE gamma rays in multi-messenger astrophysics.

109.39 — Cryocooler Systems for Improved GeD Gamma-ray Imaging and Spectroscopy

T. J. Brandt[1]; S. Banks[1]; Steve Boggs[2]; Carolyn Kierans[1]; J. Ku[1]; Steve McBride[3]; Brent Mochizuki[3]; O. Quinones[1]; Jarred Matthew Roberts[2]; A. Shih[1]; Clio Sleater[3]; John Tomsick[3]

[1] NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)

[2] University of California, San Diego (San Diego, California, United States)

[3] University of Berkeley, Space Sciences Laboratory (Berkeley, California, United States)

Placing germanium detectors (GeDs) in an MeV γ-ray Compton instrument on 100+day balloon and satellite platforms will enable unprecedented insight into nuclear line astrophysics, key multimessenger synergies, and new heliophysics applications. Compton telescopes with position-sensitive GeDs have excellent energy resolution, improved by two orders of magnitude compared to previous instruments, and are inherently sensitive to polarization. The Compton Spectrometer and Imager (COSI) 2016 balloon flight demonstrated the promise of this technology to realize key science goals.

We are developing the last critical technology components required for GeD operation on balloon and satellite platforms: cryocooler noise mitigation and associated thermal control system. We will describe our initial noise mitigation efforts, which improved the measured line width by $\sim$4. Our versatile, low cost heat pipe design maintains the cryocooler's required temperature range, while additional low risk measures will satisfy the lowest power output. We will also discuss our ongoing cryocooler noise characterization and mitigation efforts and our thermal design improvements. These developments will enable the promised improvements and thus science of COSI-X and of GRX, a SMEX mission for proposal in 2019.

109.40 — Curved X-ray Diffraction Gratings for Two Element Spectrometers

Casey T. DeRoo[1]; Randall McEntaffer[2]; Benjamin Donovan[2]; William Zhang[4]; Max Collon[3]; Nicolas Barriere[3]

[1] Department of Physics & Astronomy, University of Iowa (Iowa City, Iowa, United States)

[2] Pennsylvania State University (State College, Pennsylvania, United States)

[3] cosine Measurement Systems (Warmond, Netherlands)

[4] Goddard Space Flight Center (Baltimore, Maryland, United States)

High throughput, high resolution X-ray spectroscopy can address key questions posited by the 2010 Decadal Survey and NASA's 2013 Astrophysics Roadmap, such as how baryonic matter flows into and out of galaxies over cosmic time, and how accreting stars and black holes evolve and impact their ambient environments through feedback. In pursuit of these questions, several X-ray grating spectrometer instruments (e.g. WHIMex, AEGIS, Arcus) have been studied or proposed. All of these proposed designs feature at least three interactions with optics (reflection off of a primary and secondary mirror element, followed by diffraction by a grating) in which each interaction reduces the throughput of the instrument.

Here we report on a concept for a two element spectrometer, in which the secondary element of an X-ray mirror pair is patterned with an X-ray grating. Assuming diffraction efficiencies comparable to current X-ray reflection gratings, a two element X-ray spectrometer would increase the effective area by 30 – 50% over three element designs. In addition, this design eliminates the grating assembly, resulting in: decreased instrument mass, reduced power requirements, and cost/schedule savings by eliminating a separate grating alignment effort. We present a raytrace concept study of a diffractive X-ray mirror pair with focal lengths/radii similar to monocrystalline silicon optics (MSO) and silicon pore optics (SPO). We also review the progress made in electron beam lithography (EBL) techniques that would enable curved diffractive X-ray optics to be patterned, and outline a procedure by which the accuracy of the EBL patterning process can be measured interferometrically.

109.41 — Component Testing for X-ray Spectroscopy and Polarimetry

Alan Garner[1]; Herman Marshall[1]; Sarah Heine[1]; Ralf Heilmann[1]; Jungki Song[1]; Norbert Schulz[1]; Beverly LaMarr[1]

[1] *Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (Somerville, Massachusetts, United States)*

We describe results from testing components for potential instruments using diffraction gratings for X-ray polarimetry or high resolution X-ray spectroscopy using the MIT polarimetry beamline and monochromator. We present results on the measured absolute efficiencies of the Phase A gratings for ARCUS, a high-resolution (R∼3000) X-ray spectrometer MIDEX mission, using the Boron-K, Oxygen-K, and Carbon-K emission lines. The beamline has also been used to develop tools and techniques to measure the linear polarization of soft X-rays (0.2-0.8 keV), which form the basis for a sounding rocket mission REDSoX (Rocket Experiment Demonstration of a Soft X-ray Polarimeter) and a possible orbital mission. We present our test results of the behavior of curved prototype X-ray gratings for such a mission. Support for this work was provided in part by the National Aeronautics and Space Administration grant NNX15AL14G as well as a grant from the MIT Kavli Institute Research Investment Fund.

109.42 — Germanium Charge-Coupled Devices for Broadband X-Ray Detectors

Christopher Leitz[1]

[1] *MIT Lincoln Laboratory (Lexington, Massachusetts, United States)*

Silicon charge-coupled devices (CCDs) have been utilized for numerous X-ray astronomy missions such as *Chandra*, *XMM Newton*, and *ASCA*. These devices offer numerous advantages for X-ray detection, including large format, excellent uniformity, low read noise, good spectral resolution, and noiseless on-chip charge summation. A germanium CCD offers all of the advantages of a silicon CCD while covering an even broader spectral range. Notably, a germanium CCD offers the potential for broadband X-ray sensitivity with similar or even superior energy resolution than silicon, albeit requiring lower operating temperatures (≤ 150K) to achieve sufficiently low dark noise due to the lower band gap of this material. Germanium is commercially available in wafer diameters up to 200 mm and can be processed in the same tools used to build silicon imaging devices, enabling fabrication of large- format imaging devices. Moreover, recent advances in materials processing have yielded the high-quality semiconductor-oxide interface required for low-noise charge-coupled devices (CCDs) on germanium. Building on this advancement, MIT Lincoln Laboratory has been developing germanium CCDs for several years, with design, fabrication, and characterization of kpixel-class front-illuminated devices discussed recently. In this presentation, we outline our progress to date and describe efforts to scale these small arrays to megapixel-class imaging devices with performance suitable for scientific applications. Specifically, we discuss our efforts to increase charge-transfer efficiency, improve static yield, realize low dark and read noise, and fabricate backside- illuminated devices with excellent sensitivity.

109.43 — Enabling high-performance spectroscopy for future space-based missions

Ross McCurdy[1]; Randall McEntaffer[1]; Fabien Grisé[1]; Jake McCoy[1]; Drew Miles[1]; Ningxiao Zhang[1]; Chad Eichfeld[1]; Michael LaBella[1]; Guy Lavellee[1]

[1] *Department of Astronomy and Astrophysics, The Pennsylvania State University (State College, Pennsylvania, United States)*

High-performance spectrographs on-board upcoming missions will play an important role in addressing key questions raised in the 2010 decadal survey. The spectrographs will need to have large effective areas and be able to make high-resolution measurements of faint astronomical objects within the constraints of space-based missions. We will present our ongoing nanofabrication efforts to produce high-efficiency, high-resolution UV and X-ray reflection gratings for future NASA suborbital rocket, explorer, and large class missions. These include: optimizing electron beam lithography to better control groove parameters such as plateau size, pitch, and line edge roughness; directional ion milling to anisotropically etch a custom blazed profile into a laminar grating; thermally activated selective topography equilibrium, which creates a blazed profile by heating three dimensional staircase structures written in resist using greyscale electron beam lithography past their glass transition temperature to flow into a blazed profile; and studying the effects of potassium hydroxide etching on groove parameters. Other work includes studying how to produce a large number of grating replicas from a master grating using ultraviolet nanoimprint lithography or substrate conformal imprint lithography and testing an optical bench setup that measures grating groove density to verify it follows a radial profile.

109.44 — Observing Blazars with the Imaging X-ray Polarimetry Explorer

Herman Marshall[1]; Alan Marscher[2]
[1] *MIT Kavli Institute, MIT (Cambridge, Massachusetts, United States)*
[2] *Boston University (Boston, Massachusetts, United States)*

We will describe the potential scientific return from observations of blazars with the Imaging X-ray Polarimetry Explorer (IXPE). IXPE, planned for launch in 2021, is a NASA mission to measure polarizations of many sources in the 2-8 keV band. Blazars are often found to be highly polarized in the radio and optical bands, so we expect to detect the polarization of the X-ray light as well. We will show results from simulations of several sources and demonstrate how the imaging capability of IXPE can be used to advantage when observing the jets of nearby quasars. Typical exposure times are expected to be of order 100 ks and we also plan to observe blazars in outburst. We will be working on coordinated observations with other telescopes so that the X-ray polarization data can be properly interpreted.

Support for this work was provided in part by contract 80MSFC17C0012 from the NASA Marshall Space Flight Center.

109.45 — Analysis of the Cost, Schedule and Risk for Lynx Mirror Assembly Production

Jonathan Arenberg[1]; William Weiping Zhang[2]
[1] *Northrop Grumman Aerospace Systems (Redondo Beach, California, United States)*
[2] *Goddard Space Flight Center (Greenbelt, Maryland, United States)*

We present an analytic model for the cost, schedule and risk for the manufacture of a generalized system of many parts. The manufacturing process is represented by a series of G/G/w queues. The optimization of the manufacturing process, to minimize total process time, comes from the selection of the value of w, the number of servers performing each step in the manufacturing process. The optimal choice of w minimizes bottlenecks and idle servers. This analysis also includes the effects of finite process yield and server reliability on cost and schedule. The cost model is parameterized for the various elements of cost including the production time, thus linking the cost and schedule models. The system of coupled equations is the cost and schedule model. The general model is applied to Lynx to discuss the type of data that must be collected on the manufacturing process during the ongoing technology development process, such as process times, yields and distributions.

109.46 — Lynx Image Quality Error Budget

Jonathan Arenberg[1]; Mark Freeman[2]
[1] *Northrop Grumman Aerospace Systems (Redondo Beach, California, United States)*
[2] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

This poster presents the system level image quality error budget developed for Lynx. Lynx is the x-ray observatory mission concept developed for the Astro 2020 decadal review. Lynx's goals are half arcsecond imaging over a wide field of view. The mission requirements are decomposed and flowed into their various contributors, the intrinsic performance of the optics, aspect solution and alignment and distortions. This poster also presents the current assessment of performance against allocations.

109.47 — The Lynx X-ray Microcalorimeter

Simon Bandler[1]; James Chervenak[1]; Aaron Datesmann[1]; Archana Devasia[1]; Michael DiPirro[1]; Kazuhiro Sakai[1]; Stephen Smith[1]; Thomas Stevenson[1]; Wonsik Yoon[1]; Douglas Bennett[2]; Benjamin Mates[2]; Daniel Swetz[2]; Joel Ullom[2]; Kent Irwin[3]; Megan Eckart[4]; Enectali Figueroa-Feliciano[5]; Dan McCammon[6]; Kevin Ryu[7]; Jeffrey Olson[8]; Ben Zeiger[9]
[1] *X-ray Astrophysics Laboratory, NASA/GSFC (Greenbelt, Maryland, United States)*
[2] *NIST - Boulder (Boulder, Colorado, United States)*
[3] *Stanford University (Palo Alto, California, United States)*
[4] *LLNL (Livermore, California, United States)*
[5] *Northwester University (Evanston, Illinois, United States)*
[6] *University of Wisconsin - Madison (Madison, Wisconsin, United States)*
[7] *MIT Lincoln Laboratory (Waltham, Maryland, United States)*
[8] *Lockheed Martin Space (Palo Alto, California, United States)*
[9] *Luxel Corporation (Friday Harbor, Washington, United States)*

Lynx is an x-ray telescope, one of four large satellite mission concepts currently being studied by NASA to be a new flagship mission. One of Lynx's three instruments is an imaging spectrometer called the Lynx X-ray Microcalorimeter (LXM), an X-ray microcalorimeter behind an X-ray optic with an angular resolution of 0.5 arc-seconds and approximately 2 m^2 of area at 1 keV. The LXM will provide unparalleled diagnostics of distant extended structures and in particular will allow the detailed study of the role of cosmic feedback in the evolution of the Universe. We will describe the baseline design of LXM and the results of recent progress in the development of these technologies. The baseline sensor technology uses transition-edge sensors (TES), but we also consider an alternative approach using versus metallic magnetic calorimeters (MMC). We discuss the requirements for the instrument, the pixel layout, the baseline readout design which uses microwave Superconducting Quantum Interference Device (SQUIDs) and High-Electron Mobility Transistor (HEMT) amplifiers and the cryogenic cooling requirements and strategy for meeting these requirements.

109.48 — Hybrid CMOS Detectors for the High Definition X-ray Imager on Lynx

Samuel Hull[1]; Abraham D. Falcone[1]; Evan Bray[1]; Mitchell Wages[1]; Maria McQuaide[1]; David Burrows[1]

[1] *Department of Astronomy & Astrophysics, Pennsylvania State University (University Park, Pennsylvania, United States)*

Hybrid CMOS detectors (HCDs) are a promising active pixel sensor technology that is well suited to future high throughput X-ray telescopes, such as the High Definition X-ray Imager (HDXI) on Lynx. This instrument is baselined as a large field of view X-ray imager that takes advantage of high speed readout to avoid saturation, and small pixels to sample fine resolution X-ray optics. X-ray HCDs offer the required fast read out and small pixel size capability, while also possessing low power consumption, radiation hardness, and high detection efficiency from 0.2 keV to 10 keV. Recently, X-ray HCDs have also shown improvements in read noise and spectral resolution performance, in particular with new 12.5 micron pixel pitch devices. These detectors achieve energy resolution (FWHM) as good as 148 eV (2.5%) at 5.9 keV and 78 eV (14.9%) at 0.53 keV, and have read noise measured to be as low as 5.4 e- (RMS). Here we discuss the characteristics and performance of these small-pixel HCDs and their applicability for Lynx.

109.51 — High-resolution X-ray and gamma-ray spectroscopy with Transition-Edge Sensors

Fabian Kislat[1]; Chi C. Cheung[2]; Chris L. Fryer[4]; William Jones[5]; Henric Krawczynski[3]; James Lanzi[8]; Mark L. McConnell[1]; Takashi Okajima[6]; Daniel Schmidt[7]; David Stuchlik[8]; Daniel Swetz[7]; Joel Ullom[7]

[1] *Department of Physics and Astronomy, University of New Hampshire (Durham, New Hampshire, United States)*

[2] *NRL (Washington, District of Columbia, United States)*

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

[4] *Los Alamos National Lab (Los Alamos, New Mexico, United States)*

[5] *Princeton University (Princeton, New Jersey, United States)*

[6] *NASA's Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[7] *NIST (Boulder, Colorado, United States)*

[8] *NASA's Wallops Flight Facility (Wallops Island, Virginia, United States)*

Spectroscopy of X-ray and gamma-ray lines is one of the most powerful tools of high-energy astrophysics. In this paper we give an overview of the scientific potential of a high-energy X-ray (1-160keV) imaging telescope using an array of transition-edge sensor microcalorimeters that achieves a spectral resolution (10's of eV FWHM) far exceeding that provided by alternative focal plane designs. Valuable information can be obtained on both spatially resolvable and unresolved objects. High-energy X-ray emission originating from decays of Ti-44 (68 and 78keV) offers the possibility to study ejecta in supernova remnants in great detail and provides some of the strongest constraints on the explosion mechanism. High-energy X-ray and gamma-ray lines in the >10 keV spectra of the first few days of kilonovae resulting from neutron star mergers (NS-NS or NS-BH) provide detailed diagnostics of the ejecta and the *r*-process nucleosynthesis driving the evolving optical/IR continua. Since the discovery of a "blue turned red" optical/IR kilonova following the gravitational wave and short gamma-ray burst event, GW170817/GRB170817A, there is rejuvenated interest in high-energy spectroscopy of these events. We close by introducing the SuperCOnducTing Titanium Imager (*SCOTTI*), a proposed balloon-borne hard X-ray spectral imager that will demonstrate the technology needed for this kind of next-generation hard X-ray telescope and has the potential to make ground-breaking new measurements of the spatial and velocity distribution of Ti-44 in Cas A. Even more exciting science will be possible with a future small or medium explorer satellite, in particular to trace the evolution of the ejecta in anticipated optically- identified kilonova events.

109.52 — Glowbug, a Gamma-Ray Telescope for Bursts and Other Transients

J. Eric Grove[1]; Chi C. Cheung[1]; Matthew Kerr[1]; Lee J. Mitchell[1]; Bernard F. Phlips[1]; Richard S. Woolf[1]; Eric Wulf[1]; Colleen A. Wilson-Hodge[2]; Daniel Kocevski[2]; Michael S. Briggs[3]; Jeremy S. Perkins[4]; Sylvain Guiriec[5]; Dieter Hartmann[6]

[1] *US Naval Research Laboratory (Washington, District of Columbia, United States)*

[2] *NASA Marshall Space Flight Center (Huntsville, Alabama, United States)*

[3] University of Alabama Huntsville (Huntsville, Alabama, United States)
[4] NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)
[5] George Washington University (Washington, District of Columbia, United States)
[6] Clemson University (Clemson, South Carolina, United States)

We describe Glowbug, a gamma-ray telescope for bursts and other transients in the 30 keV to 2 MeV band. It was recently selected for funding by the NASA Astrophysics Research and Analysis program, with an expected launch in the early 2020s. Similar in concept to the Fermi Gamma Burst Monitor (GBM) and with similar sensitivity, Glowbug will join and enhance future networks of burst telescopes to increase sky coverage to short Gamma-Ray Bursts (SGRBs) from neutron star (NS) binary mergers, including possible SGRBs from NS-black hole mergers. With the recent discovery of the SGRB coincident with the gravitational wave transient GW170817, we know such events occur with reasonable frequency. Expanded sky coverage in gamma rays is essential, as more detections of gravitational waves from such mergers by ground-based interferometers will come in the next few years, and detecting an electromagnetic counterpart is a powerful probe of merger dynamics.

Work on Glowbug at NRL is supported by NASA and the Chief of Naval Research.

109.53 — Colibrì: Taking the Pulse of Black Holes and Neutron Stars

Kelsey Hoffman[1]; Daryl Haggard[2]
[1] Bishop's University (Sherbrooke, Quebec, Canada)
[2] McGill University (Montreal, Quebec, Canada)

We are developing a concept for a new Canadian-led X-ray observatory — Colibrì. The main objective of the Colibrì mission is to study the structure of accretion flows in the near vicinity of black holes and neutron stars and the study of emission from the surfaces of neutron stars. The Colibrì mission will look for answers to the questions: How do accretion disks transport material? How are relativistic jets launched? What is the structure of the spacetime surrounding black holes? What are the masses and radii of neutron stars? With high spectral and time resolution, and high throughput, Colibrì will allow the study of accretion disks and coronae, including reflection and re-emission of radiation by the disk, and observations of isolated and accreting neutron stars.

The Colibrì concept concept is based on multiple aperture non-imaging X-ray collectors similar to NICER but with cryogenically cooled transition edge detectors for high energy resolution and sensitivity. Colibrì aims to achieve an energy resolution finer than 1eV at 2keV, and count rates up to 10kHz, in an energy range of 0.5-10 keV. The timing of Colibrì aims to be better than 1 micro-sec, matching the innermost orbit period for a 10 solar-mass black hole. The total effective area of Colibrì is to be at least 2000 cm^2 at 6.4 keV. This concept study is being funded by the Canadian Space Agency.

109.54 — MoonBEAM: A Beyond Earth-orbit Gamma-ray Burst Detector for Multi-Messenger Astronomy

Chiumun Michelle Hui[1]; Michael S. Briggs[2]; Eric Burns[3]; Corinne Fletcher[3]; Adam Goldstein[3]; Peter A. Jenke[2]; Daniel Kocevski[1]; Oliver Roberts[3]; Colleen A. Wilson-Hodge[1]
[1] Department of Astrophysics, NASA Marshall Space Flight Center (Huntsville, Alabama, United States)
[2] University of Alabama in Huntsville (Huntsville, Alabama, United States)
[3] Universities Space Research Association (Huntsville, Alabama, United States)

Moon Burst Energetics All-sky Monitor (MoonBEAM) is a CubeSat concept of deploying gamma-ray detectors in cislunar space to increase gamma-ray burst detections and improve localization precision with the timing triangulation technique. A gamma-ray instrument in cislunar orbit will have greatly reduced sky blockage compared to instruments in low Earth orbit. Working in conjunction with another instrument in low Earth orbit, MoonBEAM can also help constrain the arrival direction of the wavefront to an annulus on the sky by utilizing the light arrival times between the different orbits. This method has been demonstrated by the Interplanetary Gamma-Ray Burst Timing Network. However, delays in data downlink for instruments outside the Tracking and Data Relay Satellite network prevent rapid follow-up observations. We present here a gamma-ray CubeSat concept in Earth-Moon L3 halo orbit that is capable of faster response and provide a timing baseline for localization improvement. Such an instrument would aid in the gravitational wave follow-up observations in other wavelengths to identify the gamma-ray burst afterglow and kilonova emission. Reducing the region of interest makes identifying afterglows much faster, allowing for rapid on-source observations and monitoring of the rise and decay times. It will also prevent source confusion between two transients and enable robust association. A gamma-ray detection could also increase the confidence of a simultaneous but marginal gravitational wave signal, extending the detection horizon.

109.55 — AdEPT, the Advanced Energetic Pair Telescope for Medium-Energy Gamma-Ray Polarimetry

Stanley D. Hunter[1]; Lorella Angelini[1]; Andrey Timokhin[1]

[1] *Astroparticle Physics Laboratory, NASA/GSFC (Greenbelt, Maryland, United States)*

The Advanced Energetic Pair Telescope (AdEPT) is being developed as a future NASA/GSFC end-to-end MIDEX mission to perform high-sensitivity medium- energy (5–200 MeV) astronomy and revolutionary gamma-ray polarization measurements. The enabling technology for AdEPT is the GSFC Three-Dimensional Track Imager (3-DTI), a large volume gaseous time projection chamber with 2-dimentional micro-well detector (MWD) readout. The low density and high spatial resolution of the 3-DTI allows AdEPT to achieve high angular resolution ($\sim$0.5 deg at 67.5 MeV) and, for the first time, exceptional gamma- ray polarization sensitivity. These capabilities enable a wide range of scientific discovery potential for AdEPT. The key science goals of the AdEPT mission include: 1) Explore fundamental processes of particle acceleration in active astrophysical objects, 2) Reveal the magnetic field configuration of the most energetic accelerators in the Universe, 3) Explore the origins and acceleration of cosmic rays and the Galactic MeV diffuse emission, 4) Search for dark matter in the Galactic center, and 5) Test relativity with polarization measurements. We report on the development of AdEPT as a future NASA/GSFC MIDEX mission to perform high-sensitivity medium-energy (5–200 MeV) astronomy and revolutionary gamma-ray polarization measurements.

109.56 — Evaluating the Polarization Performance of the Compton Spectrometer and Imager (COSI)

Hadar Lazar[1]; Alex Lowell[2]; Jacqueline Beechert[1]; Steve Boggs[2,1]; T. J. Brandt[3]; Carolyn Kierans[3]; Steve McBride[1]; Brent Mochizuki[1]; Jarred Matthew Roberts[2]; Clio Sleater[1]; John Tomsick[1]; Chien-Ying Yang[4]; Andreas Zoglauer[1]

[1] *Department of Physics, University of California, Berkeley (Berkeley, California, United States)*

[2] *University of California, San Diego (San Diego, California, United States)*

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

[4] *National Tsing Hua University (Hsinchu City, Taiwan)*

The Compton Spectrometer and Imager (COSI) is a balloon-borne compact Compton telescope operating in the 0.2-5.0 MeV energy range with inherent sensitivity to polarization. One of COSI's goals is to better understand the geometry and emission processes of astrophysical phenomena such as gamma-ray bursts and compact objects by measuring their polarization through the distribution of the azimuthal Compton scattering angles of the incident gamma rays. A polarization calibration apparatus was built to evaluate the detector response over a large energy band pass and the whole field of view. Partially polarized beams were created by scattering gamma rays from a radioactive source off of a scintillator over a range of Compton and polar angles. The measured responses were then compared and benchmarked to simulations to fine- tune the detector effects engine. The residual deviations will allow us to place an upper limit on the systematic uncertainty. The benchmarked simulations will also be used to create simulated polarization response files to analyze the polarization of COSI observations of astrophysical sources. The results of this test will be applied toward instrument calibration for future COSI missions, and the calibration apparatus and procedure will be adapted for future telescope upgrades.

109.57 — The STROBE-X Mission Science Case

Thomas J. Maccarone[1]

[1] *Department of Physics & Astronomy, Texas Tech University (Lubbock, Texas, United States)*

STROBE-X is a Probe class mission concept aimed at revolutionizing X-ray timing. Its three instruments are a Large Area Detector, with collecting area and energy resolution about 10 times as good as RXTE's, an X-ray Concentrator Array with collecting area about ten times as good as NICER's, and a Wide Field Monitor, with about 10 times the instantaneous solid angle as BeppoSax's wide field camera, and with full event mode telemetry, making use of its near- CCD quality energy resolution. Here, we will present key science cases for the mission, focusing on understanding the spins of stellar mass and supermassive black holes, understanding the equation of state of neutron stars, understanding the electromagnetic counterparts to multi-messenger signals, and making a variety of contributions across the range of stellar astrophysics, accretion physics, and extragalactic survey science.

109.58 — HEX-P: The High-Energy X-ray Probe

Kristin Madsen[1]; Daniel Stern[2]; Brian Grefenstette[1]; Hiromasa Miyasaka[2]; Javier A. García[1]

[1] *SRL, Caltech (Glendale, California, United States)*

[2] *JPL (La Canada, California, United States)*

The High-Energy X-ray Probe (HEX-P) is a probe-class next-generation high- energy X-ray observatory mission concept that will vastly extend the reach of broadband X-ray observations. Observing over the 2-200 keV energy range, HEX-P has 40 times the sensitivity of any previous mission in the 10-80 keV band, and 10,000 times the sensitivity of any previous mission in the 80-200 keV band. A successor to the Nuclear Spectroscopic Telesceope Array (NuSTAR), a NASA Small Explorer launched in 2012, HEX-P addresses key NASA science objectives. HEX-P is also an important complement to ESA's Athena mission, which emphasizes high-resolution spectroscopy below 10 keV. Together, HEX-P and Athena would provide a powerful capability for addressing a diverse range of questions central to modern astrophysics, working independently or in coordinated observations as the science demands. HEX-P will provide fundamental new discoveries that range from probing the extreme environments around black holes and neutron stars, to mapping the growth of supermassive black holes and probing the effect they have on their environments. Based on NuSTAR heritage, HEX-P requires only modest technology development, and could easily be executed within the next decade.

109.59 — The X-ray Polarization Probe Concept Study

Herman Marshall[1]; Keith Jahoda[2]; Henric Krawczynski[3]; Fabian Kislat[4]

[1] *MIT Kavli Institute, MIT (Cambridge, Massachusetts, United States)*

[2] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[3] *Washington University (St Lous, Missouri, United States)*

[4] *University of New Hampshire (Durham, New Hampshire, United States)*

The X-ray Polarization Probe (XPP) is designed to be a follow-on to the Imaging X-ray Polarimetry Explorer (IXPE), deepening and broadening the field of X-ray polarimetry. IXPE is scheduled for launch in 2021 and will be the first instrument to measure the X-ray polarizations of dozens of sources of many types, such as Galactic X-ray binaries, supernova remnants (SNRs), magnetars, and active galactic nuclei (AGN). The IXPE instrument is sensitive in the 2-8 keV band with an imaging resolution of about 25″, sufficient to resolve shock fronts of SNRs and separately measure pulsars and their wind nebulae. XPP would broaden the bandpass by including a polarimeter sensitive down to 0.1 keV as well as one for measuring polarization up to 60 keV. XPP would be more 3-10 times more sensitive than IXPE (in the 2-8 keV band) with larger focussing mirrors. In addition, the imaging resolution would be improved to 5-10″, enabling more resolution of SNRs and resolving AGN jets. Other science goals of XPP will be presented, including measuring the spins of Galactic stellar-mass black holes, testing models of the geometry of AGN coronae, observing the polarization in the cyclotron resonant scattering features in Galactic accreting pulsars, and searching for axion-like particles.

109.60 — Ex Luna, Scientia: MeV Gamma-Ray Astrophysics with the Lunar Occultation eXplorer (LOX)

Richard Scott Miller[1]; Marco Ajello[2]; John F. Beacom[3]; Peter F. Bloser[4]; Adam Burrows[5]; Chris L. Fryer[8]; John O. Goldsten[1]; Dieter Hartmann[2]; Peter Hoeflich[6]; Aimee L. Hungerford[8]; David J. Lawrence[1]; Mark D. Leising[2]; Peter Milne[7]; Patrick N. Peplowski[1]; Lih-Sin The[2]

[1] *SES/SRE, Johns Hopkins University Applied Physics Laboratory (Laurel, Maryland, United States)*

[2] *Clemson University (Clemson, South Carolina, United States)*

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

[4] *University of New Hampshire (Durham, New Hampshire, United States)*

[5] *Princeton University (Princeton, New Jersey, United States)*

[6] *Florida State University (Tallahassee, Florida, United States)*

[7] *University of Arizona-Steward Observatory (Tucson, Arizona, United States)*

[8] *Los Alamos National Laboratory (Los Alamos, New Mexico, United States)*

Astronomical investigations from the Moon afford new opportunities to advance our understanding of the cosmos. The Lunar Occultation Explorer (LOX) will leverage the power of a new observational technique to transform our understanding of the nuclear cosmos (0.1–10 MeV) and establish the Moon as a platform for astrophysics. LOX directly challenges traditional paradigms like Compton telescopes by mitigating mission complexity, technology development lifecycles, and cost constraints, while also delivering the sensitivity and continuous all-sky monitoring capabilities needed to transform nuclear gamma- ray (MeV) astrophysics. In its baseline configuration LOX is capable of surveying the entire sky at a bolometric sensitivity $<10^{-7}$ cm^{-2} s^{-1}

MeV^{-1}, near-continuous monitoring of astrophysical light curves, and arcminute source localizations.

LOX will operate from lunar orbit and use the Moon as a natural occulting disk to modulate astrophysical source signatures via repeated eclipses. Simplicity is a hallmark of this efficient and validated approach, and the resulting occultation ensembles contain all information necessary for source detection, characterization and localization. LOX's lone instrument, the Big Array for Gamma-ray Energy Logging (BAGEL) is highly scalable, limited only by available mission mass and power resources, and data analyses rely only on detailed knowledge of the spacecraft ephemerides and a rigorous statistical framework rather than kinematic reconstruction. LOX's deployment to the Moon and use of time series-based analyses benefits from 20+ years of successful lunar exploration using gamma-ray spectrometers and mimics the operational profile of planetary orbital geochemistry investigations.

LOX is a mature, low-risk, and high-heritage implementation. Its viability as a competitive next-generation nuclear astrophysics mission, including in-situ validation of the technique from lunar orbit, and the benefits of the lunar environment, will be presented. Several high-priority science goals will also be reviewed to highlight the unique insights LOX can reveal about the lifecycle of matter and energy in our galaxy and beyond.

109.62 — A Front-End ASIC for High Purity Germanium Strip Detector Astrophysics Experiments

Jarred Matthew Roberts[1]; Eric Wulf[2]; Gianluigi De Geronimo[4]; Steve Boggs[1,3]; John Tomsick[3]; Brent Mochizuki[3]; Steve McBride[3]; Pascal Saint-Hilaire[3]

[1] *University of California at San DIego, Center for Astrophysics and Space Sciences (La Jolla, California, United States)*

[2] *Naval Research Laboratories (Washington, District of Columbia, United States)*

[3] *University of California at Berkeley, Space Sciences Laboratory (Berkeley, California, United States)*

[4] *Stony Brook University, Department of Electrical Engineering (Stony Brook, New York, United States)*

A front-end application specific integrated circuit (ASIC) designed for high-purity germanium (HPGe) strip detector astrophyscs experiments like the Compton Spectrometer and Imager (COSI-X), has be fabricated and tested. Recent results on the the ASIC's performance characteristics after integration with HPGes originally developed for the Gamma-Ray Imager/Polarimeter for Solar flares (GRIPS), are presented. The ASIC contains 32 channels and can instrument either cathode or anode signals from the HPGe detector. The ASIC has a small noise slope allowing it to maintain germanium energy resolution at the large, 30 pF, input capacitance of a germanium strip detector connected through the cryostat by a kapton flex cable. The channels provide low-noise charge amplification, four shaping times, four gain ranges, trimmable discrimination for each channel, time to analog output, and peak detectors with analog memory. The channels process events in parallel and the ASIC emits a logical-OR of the internal discriminators for external control. The ASIC sparsifies the triggered channels for low deadtime readout. Each channel dissipates 6.2 mW and covers an energy range up to 4 MeV in HPGe. Measurements have demonstrated an equivalent noise charge (ENC) of 260 electrons, at an input capacitance of 32.5 pF with a slope of 6.4 electrons/pF for a peaking time of 2 μs.

109.63 — Benchmarking simulations of the Compton Spectrometer and Imager with calibrations

Clio Sleator[1]; Andreas Zoglauer[1]; Jacqueline Beechert[1]; Steve Boggs[2]; T. J. Brandt[3]; Hadar Lazar[1]; Alex Lowell[2]; Carolyn Kierans[3]; Nick Pellegrini[1]; Jarred Matthew Roberts[2]; John Tomsick[1]

[1] *Space Sciences Lab, UC Berkeley (Berkeley, California, United States)*

[2] *UC San Diego (San Diego, California, United States)*

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

The Compton Spectrometer and Imager (COSI) is a balloon-borne gamma-ray (0.2-5 MeV) telescope designed to study astrophysical sources. COSI's main science goals are to measure polarization from gamma-ray bursts and compact objects, map the 511-keV positron annihilation line from the Galactic bulge and plane, and image diffuse Galactic emission with nuclear lines. COSI employs a compact Compton telescope design utilizing 12 high-purity germanium double-sided strip detectors and is inherently sensitive to polarization. In 2016, COSI was launched from Wanaka, New Zealand and completed a successful 46-day flight on NASA's new Superpressure balloon. In order to perform imaging, spectral, and polarization analysis of the sources observed during the 2016 flight, we must accurately simulate the detector response. To achieve this goal, we have built a comprehensive mass model of the instrument and developed a detailed detector effects engine which applies the intrinsic detector performance to Monte Carlo simulations. The simulated detector effects include energy, position, and timing resolution, thresholds, dead strips, dead time, and detector trigger conditions. After this step, the simulations closely resemble the measurements, and the standard analysis pipeline used for measurements can also be applied to the simulations. In this presentation, we will describe the detector effects engine and the benchmarking tests performed with calibrations. We will also describe the application of these benchmarked simulations to create COSI's detector response.

109.64 — Gravitational Wave Counterparts with the Nimble Mission Concept

Jacob Russell Smith[1]
[1] *Department of Astrophysics, NASA/GSFC (Riverdale, Maryland, United States)*

Nimble is a NASA Explorer class mission concept that couples a very wide- field gamma ray monitor with a multiwavelength telescope and rapid response spacecraft. The primary mission science is focused on detection and characterization of compact binary mergers (most likely binary neutron star or neutron star/black hole) through characterizing short gamma-ray bursts and kilonovae. Nimble's High-energy All-sky Monitor (HAM) and Small UV-Optical-IR (SUVOIR) instruments together will detect, localize, and characterize gravitational wave counterparts, and disseminate that information to the ground for additional rapid follow-up observations. In addition to detecting short gamma-ray bursts followed by their afterglow/kilonova counterparts, Nimble will be able to quickly respond to external triggers from the ground- based gravitational wave network or other triggering instruments. The broad gamma-ray and UVOIR observations will trace the evolution of these events and their cosmic chemical enrichment, explore the structure and origin of their emission mechanisms, and be probes of fundamental physics and cosmology.

109.65 — Arcus, The Soft X-ray Grating Explorer

Randall Smith[1]
[1] *HEAD, Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

Arcus provides high-resolution soft X-ray spectroscopy in the 12-50Å bandpass with sensitivity orders of magnitude higher than any previous astronomical observatory. Its capabilities include spectral resolution >2500 and effective area of $\sim$250 cm^2. The three top science goals for Arcus are to (1) measure the effects of structure formation imprinted upon the hot baryons that are predicted to lie in extended halos around galaxies, groups, and clusters, (2) trace the propagation of outflowing mass, energy, and momentum from the vicinity of the black hole to extragalactic scales as a measure of their feedback and (3) explore how stars, circumstellar disks and exoplanet atmospheres form and evolve. Arcus relies upon the same 12m focal length grazing-incidence silicon pore X-ray optics (SPO) that ESA has developed for the Athena mission; the focal length is achieved on orbit via an extendable optical bench. The focused X-rays from these optics are diffracted by high-efficiency Critical-Angle Transmission (CAT) gratings, and the results are imaged with flight-proven CCD detectors and electronics. The power and telemetry requirements on the spacecraft are modest and mission operations are straightforward, as most observations will be long, uninterrupted, and pre- planned.

109.66 — Tracking Earth-skimming Ultra-high Energy Tau Neutrinos Back to the Extreme Universe

Tonia Venters[1]*; Mary Hall Reno*[2]*; John Krizmanic*[3,4]
[1] *Astrophysics Science Division, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[2] *University of Iowa (Iowa City, Iowa, United States)*
[3] *CRESST/NASA GSFC (Greenbelt, Maryland, United States)*
[4] *University of Maryland, Baltimore County (Baltimore, Maryland, United States)*

The highest energy cosmic rays are the messengers of the most extreme physics in the cosmos; however, efforts to identify their origins have thus far been thwarted by the fact that they don't point back to their sources. On the other hand, interactions between ultra-high energy cosmic rays (UHECR) and the lower energy particles that they encounter either within their sources or over the course of their cosmic journey will give rise to ultra-high energy neutrinos. Leveraging the Earth as a neutrino converter, several next- generation multi-messenger experiments will study ultra-high energy tau neutrinos in order to unravel the mysteries of UHECR acceleration and composition and the evolution of their sources. We present the results of detailed simulations propagating ultra-high energy tau neutrinos through the Earth and generating optical Cherenkov radiation from extensive air showers arising from generated tau leptons. We apply the concept study parameters for the Probe of Extreme Multi-Messenger Astrophysics (POEMMA) to illustrate how such simulations can be used to determine instrumental capabilities for detecting Earth-skimming tau neutrinos via Cherenkov radiation.

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

Scott Wolk[1]
[1] *High energy, Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

The first and easiest detected exo-planets 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; (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 planets. 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.

109.68 — Next Generation Astronomical X-ray Optics: High Resolution, Light Weight, and Low Cost

William Weiping Zhang[1]
[1] *X-ray Astrophysics Laboratory, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The state of the art of astronomical X-ray optics, represented by the three currently operating missions, *Chandra*, XMM-*Newton*, and NuSTAR, requires tradeoffs among three highly desirable quantities: 1) angular resolution, 2) effective area, and 3) production cost. Future astronomical missions require X-ray mirror assemblies that are qualitatively better in all the three quantities: better angular resolution, larger effective area per unit mass, lower production cost per unit effective area. In this paper we report on a comprehensive X-ray astronomical optics development program at NASA Goddard Space Flight Center that has the potential to qualitatively advance the state of the art of X-ray optics manufacturing in all the three quantities: angular resolution, effective area, and production cost. It is based on precision-polishing of mono-crystalline silicon to make lightweight and thin mirror segments, coating of iridium film to maximize effective area, and an alignment and integration process that, as intermediary steps, constructs modules and meta-shells which are subsequently integrated into a mirror assembly. We will report on optical design, mechanical design, thermal design, and stray light baffle design of a mirror assembly as well as test results of technology development modules, showing that sub-arcsecond lightweight X-ray telescopes can be realized to meet large effective area, light weight, low production cost, and schedule requirements of future missions, including Explorer class missions such as the Survey and Time-domain Astrophysical eXplorer (STAR-X) and the Focusing On Relativistic universe and Cosmic Evolution(FORCE), Probe missions such as the Advanced X-ray Imaging Satellite (AXIS) and the Transient Astrophysics Probe (TAP), as well as flagship missions such as Lynx.

109.69 — Nimble: A Mission Concept for Gravitational Wave Counterpart Astrophysics

Joshua Schlieder[1]
[1] *Exoplanets and Stellar Astrophysics Laboratory, NASA GSFC (Greenbelt, Maryland, United States)*

In August 2017, the first gravitational waves from merging neutron stars were detected coincident with a short gamma-ray burst (sGRB) and triggered a world-wide observing campaign to identify and characterize the associated kilonova emission. This event led to numerous firsts and discoveries that began to unveil the mysteries of these energetic astronomical phenomena. However, many questions remain and the field of multimessenger astrophysics is prime for further discovery. Here we describe *Nimble*, a NASA Explorers class mission concept that couples a very wide-field gamma ray monitor with a multiwavelength telescope and rapid response spacecraft to enable the prompt detection and localization of sGRBs and follow-up of kilonovae. We will describe the science drivers for *Nimble* and detail the current engineering concept. *Nimble* will discover and characterize the counterparts of neutron star merger gravtitational wave events and its flexible platform will allow for a wide range of additional multiwavelength time domain science.

109.70 — Multi-Messenger Astronomy with Nimble and Coordinated X-ray Observations

Kimberly Ann Weaver[1]; *Joshua Schlieder*[1]
[1] *X-ray Astrophysics, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

With the detection of gravitational waves and electromagnetic emission from a neutron star merger (GW170817/GRB170817A), multi-messenger astronomy has become a new tool for astrophysical study. Nimble is a NASA Explorers class mission concept designed to detect and localize the short gamma-ray bursts that are associated with gravitational wave events, rapidly slew to identify their kilonova counterparts, and perform detailed UV-Optical-IR (UVOIR) follow-up. This broad gamma-ray and UVOIR sensitivity will allow Nimble to explore the emission mechanisms of these events, place constraints on heavy element production, and probe fundamental physics. In the X-ray band, Chandra detected an X-ray afterglow for GRB170817A nine days post-merger, and it was a surprising discovery that XMM observed the X-ray afterglow still strong 135 days after the merger event. If X-ray afterglows typically occur weeks to months post-merger, then XMM can observe all such events. We discuss the logistics of coordination between Nimble and XMM to trigger X-ray follow-up of neutron star mergers and the science to be discovered, as well as the potential for coordinated follow up with other X-ray missions.

109.71 — PBP: A Slumped Micropore Optic Simulator

K. D. Kuntz[1]; *F. Scott Porter*[2]; *N. E. Thomas*[2,3]
[1] *Department of Physics & Astronomy, Johns Hopkins University (Baltimore, Maryland, United States)*
[2] *Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[3] *Unibersity of Maryland Baltimore County (Baltimore, Maryland, United States)*

Slumped micropore optics (lobster-eye optics) have been proposed for a number of wide-field X-ray imagers in both astro- and helio-physics (SVOM, TAO, DXG, CuPID, SMILE and STORM). We have developed a Pore-By-Pore simulator for such optics which has been used to simulate the throughput for a number of missions. This work describes the fundamental equations and overall philosophy for this simulator, as well as the equations and structure required for a more rigorous modeling of the shape and size of the PSF. The PSF modeling will be included in the next generation Pore-By-Pore simulator.

109.72 — Telescope Design for the LISA Mission

Jeffrey Livas[1]
[1] *Gravitational Astrophysics Laboratory, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The Laser Interferometer Space Antenna (LISA) Mission Proposal has been selected for the L3 Launch Opportunity for ESA's Cosmic Visions Program. A space-based gravitational wave observatory is expected to see a rich array of astrophysical sources in a frequency band from 0.1 mHz to 0.1 Hz. The instrument operates by ranging between free-flying test masses as demonstrated by the LISA Pathfinder Mission. The ranging system requires an optical telescope to efficiently transfer light between the test masses, spaced 2.5 Gm apart. The requirements and current design for this optical telescope are described.

109.73 — Characterization of Slumped Micropore Optics

Nicholas Evan Thomas[1,2]
[1] *University of Maryland, Baltimore County (Baltimore, Maryland, United States)*
[2] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

Slumped micropore optics are a promising technology that allows for very wide field-of-view observations up to 23 degrees with the added benefit of a low mass per unit collection area as compared to conventional X-ray telescope optics. Also known as lobster-eye optics, they will be employed by a number of X-ray telescopes that are proposed or currently under development (SVOM, TAO, DXG, CuPID, SMILE and STORM). We are currently characterizing these optics at the Goddard 100 meter beamline where the focal plane image gives both the PSF and the energy dependent collecting area. We currently find that the typical PSF is 9 arc minutes FWHM and the response of the optics is ~90% of that predicted by a ray tracing model. A new slumped micropore optic test stand allows for similar measurements to be made in lab, with similar results to those measured at a traditional X-ray beamline.

109.74 — Wide-field Hard X-ray Survey with the Astronomical Roentgen Telescope X-ray Concentrator

Chien-Ting Chen[1]; Douglas Swartz[1]; Vyacheslav Zavlin[1]; Roman Krivonos[2]; Ilya Mereminskiy[2]; Mikhail Pavlinsky[2]; Alexey Tkachenko[2]
[1] *USRA/MSFC (Huntsville, Alabama, United States)*
[2] *IKI (Moscow, Russian Federation)*

The Astronomical Roentgen Telescope X-ray Concentrator (ART-XC) instrument onboard the Spectrum Röntgen Gamma (SRG) mission will survey the entire sky in the hard energy band, 5-30 keV, beginning approximatly 100 days after the scheduled March 2019 launch. The observations of the ecliptic pole regions will reach exceptional depth thanks to the survey design of overlapping exposure in these regions. In anticipation of the ART-XC survey in the North Ecliptic Pole (NEP) region, we explore publicly available multiwavelength catalogs in the NEP region and investigate AGN candidates that might exhibit hard X-ray signals that will be detected by ART-XC. To capitalize on the ART- XC coverage in the NEP region, we also investigate ART-XC cadence and sensitivity limits for a selected few luminous X-ray sources. We also describe data analysis and simulation tools being made available to the public.

109.75 — ART-XC Mission Update

Douglas Swartz[1]; Mikhail Pavlinsky[2]; Roman Krivonos[2]; Alexey Tkachenko[2]; Ilya Mereminskiy[2]; Chien-Ting Chen[1]; Vyacheslav Zavlin[1]
[1] *USRA/MSFC (Huntsville, Alabama, United States)*
[2] *IKI (Moscow, Russian Federation)*

We present an overview of the Astronomical Roentgen Telescope – X-ray Concentrator (ART-XC) instrument on board the Spectrum-Roentgen-Gamma (SRG) mission currently scheduled for launch in 2019. ART-XC is an X-ray grazing incidence mirror telescope array developed by the Space Research Institute (IKI) and the All-Russian Scientific Research Institute for Experimental Physics (VNIIEF). NASA's Marshall Space Flight Center (MSFC) developed and fabricated the X-ray mirrors. ART-XC is composed of seven mirror modules co- aligned with seven CdTe double-sided strip focal plane detectors. ART-XC will operate over the energy range of 4–30 keV, with an angular resolution of <1', a field of view of ~0.3 square degree and an expected energy resolution of about 9% at 14 keV. The ART-XC primary mission will be to perform a four-year all-sky survey simultaneously with the other SRG instrument, eROSITA, followed by three years of pointed observations.

109.76 — Study of the Systematic Errors of the Polarization Fraction and Angle Measurements with the X-Calibur Hard X-ray Polarimetry Mission

Quincy Abarr[1]; Richard Bose[1]; Dana Braun[1]; Gianluigi De Geronimo[2]; Paul Dowkontt[1]; Manel Errando[1]; Thomas Gadson[3]; Victor Guarino[4]; Scott Heatwole[3]; Nirmal Iyer[5,6]; Fabian Kislat[7]; Mózsi Kiss[5,6]; Takao Kitaguchi[8]; Henric Krawczynski[1,9]; Rakhee Kushwah[5,6]; James Lanzi[3]; Shaorui Li[10]; Lindsey Lisalda[1]; Takashi Okajima[11]; Mark Pearce[5,6]; Zachary Peterson[3]; Rauch Brian[1]; David Stuchlik[3]; Hiromitsu Takahashi[12]; Nagomi Uchida[12]; Andrew West[1]
[1] *Washington University in St. Louis (St. Louis, Missouri, United States)*
[2] *Brookhaven National Laboratory (Upton, New York, United States)*
[3] *Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[4] *Hiroshima University (Hiroshima, Japan)*
[5] *Stony Brook University (Stony Brook, New York, United States)*
[6] *Wallops Flight Facility (Wallops Island, Virginia, United States)*
[7] *Guarino Engineering (Oak Park, Illinois, United States)*
[8] *KTH (Stockholm, Sweden)*
[9] *OKCCP (Stockholm, Sweden)*
[10] *University of New Hampshire (Durham, New Hampshire, United States)*
[11] *RIKEN (Wako, Japan)*
[12] *McDonnell Center for the Space Sciences (St. Louis, Missouri, United States)*

The hard X-ray polarimeter X-Calibur was flown on a short stratospheric balloon flight from Dec. 29, 2018 to Jan. 1, 2019. X-Calibur's main objective is to measure the linear polarization fraction and angle of the 15-60 keV emission from galactic X-ray binaries and extragalactic active galactic nuclei. We report here on a study of the systematic errors on the measured polarization properties, based on pre-flight calibration measurements, detailed Monte Carlo simulations of the detector performance, and the data gathered during the flight.

109.77 — Recent progress on the Off-plane Grating Rocket Experiment

Benjamin Donovan[1]
[1] *Department of Astronomy & Astrophysics, Pennsylvania State University (University Park, Pennsylvania, United States)*

The Off-plane Grating Rocket Experiment is a soft X-ray grating spectrometer payload to be launched on a suborbital rocket. The spectrometer hopes to achieve the highest resolution soft X-ray spectrum to date when launched – R > 2000. Critical to performance goal of the spectrometer are the performance of each of its components: monocrystalline silicon optics developed by NASA Goddard Space Flight Center, X-ray reflection gratings from The Pennsylvania State University, and electron-multiplying CCDs from XCAM Ltd. & The Open University. We report on recent project developments, including performance testing of prototype reflection gratings and X-ray optics designed for this payload as well as the expected performance of the payload.

109.78 — Performance of the X-Calibur Hard X-ray Polarimetry Mission During the 2018-2019 Long Duration Balloon Flight

Fabian Kislat[1]; Quincy Abarr[2]; Richard Bose[2]; Dana Braun[2]; Gianluigi De Geronimo[3]; Paul Dowkontt[2]; Manel Errando[2]; Thomas Gadson[4]; Victor Guarino[5]; Scott Heatwole[4]; Nirmal Iyer[6]; Mózsi Kiss[6]; Takao Kitaguchi[7]; Henric Krawczynski[2]; Rakhee Kushwah[6]; James Lanzi[4]; Shaorui Li[8]; Lindsey Lisalda[2]; Takashi Okajima[9]; Mark Pearce[6]; Zachary Peterson[4]; Brian Rauch[2]; David Stuchlik[4]; Hiromitsu Takahashi[10]; Nagomi Uchida[10]; Andrew West[2]

[1] *Department of Physics and Astronomy, University of New Hampshire (Durham, New Hampshire, United States)*

[2] *Hiroshima University (Hiroshima, Japan)*

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

[4] *Stony Brook University (Stony Brook, New York, United States)*

[5] *NASA's Wallops Flight Facility (Wallops Island, Virginia, United States)*

[6] *Guarino Engineering (Oak Park, Illinois, United States)*

[7] *KTH (Stockholm, Sweden)*

[8] *RIKEN (Wako, Japan)*

[9] *Brookhaven National Lab (Upton, New York, United States)*

[10] *NASA's Goddard Space Flight Center (Greenbelt, Maryland, United States)*

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 relatively short stratospheric balloon flight from McMurdo (Antarctica) from Dec. 29, 2018 to Jan. 1, 2019, during which it observed GX 301-2 and Vela X-1. Here, we report on the performance of the instrument during this flight and the measured background levels.

109.79 — The Next-Generation Balloon-Borne Hard X-ray Polarimeter XL-Calibur

Fabian Kislat[1]

[1] *Department of Physics and Astronomy, University of New Hampshire (Durham, New Hampshire, United States)*

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. *X-Calibur* is a balloon-borne hard X-ray polarimeter covering the 20-40keV energy range consisting of an 8m long optical bench carrying the *InFOCμS* hard X-ray mirror, and a scattering polarimeter at its focal point.

Here we present a powerful follow-up mission, *XL-Calibur*, with a 6-times greater sensitivity. *XL-Calibur* will consist of an enhanced scattering polarimeter based on the *X-Calibur* design in the focal plane of the spare hard X-ray mirror of the Japanese *Hitomi* mission. The 12m-focal-length mirror increases the effective area in the core energy region from 20-40keV by a factor of 4 and even more at higher energies, increasing the bandwidth of *XL-Calibur* as compared to *X-Calibur*. Furthermore, the polarimeter will use a more compact design and thinner CZT detectors, significantly reducing the background. We conclude with a discussion of the neutron star, accretion physics, and fundamental physics constraints that can be obtained with this mission.

109.80 — Background Modeling for the Balloon-Borne Gamma Ray Polarimeter Experiment (GRAPE)

Sambid Wasti[1]

[1] SSC, University of New Hampshire (Durham, New Hampshire, United States)

The Gamma Ray Polarimeter Experiment (GRAPE), a balloon borne Compton polarimeter for studying 50-300 keV gamma rays. The payload has flown twice (in 2011 and 2014) with the primary goal being to measure the polarization from the Crab Nebula/Pulsar. Understanding the background is a fundamental part of the the instrument design. The background arises from the interaction of cosmic ray and atmospheric radiations with the instrument. Published parameterizations of these various radiation components have been used to simulate the instrument background using the GEANT4 simulation toolkit. The initial simulations resulted in background estimates that were not consistent with the measured background. These discrepancies have been resolved by including the effects of optical crosstalk that is known to exist within each polarimeter module. For each balloon flight, the payload was comprised of an array of independent polarimeter modules. Each module consists of an array of small scintillator elements on the from end of a multi-anode PMT (MAPMT). Ideally, the light from each scintillator element is collected by one and only one anode of the MAPMT. However, there is a known issue with optical crosstalk that arises from light exiting the scintillator elements and spreading across several anodes. This crosstalk can result in the misclassification of recorded events. A model was developed to represent the crosstalk, which was subsequently incorporated into our simulations. The resulting simulations show significantly improved agreement with the measured background. Simulations with the crosstalk modeling are now being used to model the instrument response.

109.81 — Background Estimation for a Balloon Borne Gamma-Ray Experiment (GRAPE)

Sambid Wasti[1]

[1] SSC, University of New Hampshire (Durham, New Hampshire, United States)

The Gamma Ray Polarimeter Experiment (GRAPE), a balloon borne polarimeter for 50∼300 keV gamma rays, successfully flew in 2011 and 2014. GRAPE consists of collimated array of polarimeter modules. The primary goal of these balloon flights was to measure the gamma ray polarization of the Crab Nebula.A good background estimation is crucial for this measurement. GRAPE observed various different sky regions before crab was in the range of the instrument. It observed the sun, cygnus-X1 and two separate background regions in the sky where we had no known sources above our instrument's threshold. Additionally the cygnus-X1 and the sun were also not active and were below our instrument threshold. So these measurements were also treated as background measurements.The background depends on many flight and instrument parameters including altitude, instrument pointing, temperatures, etc. We wanted to use these parameters and the background measurements to get an estimate for the Crab observation. These parameters are varying throughout the flight so estimating the background for the Crab observation was quite challenging. We have developed a technique based on the Principle Component Analysis (PCA) to identify the influential parameters. We found that the background depended mostly on the atmospheric depth, pointing zenith angle and instrument temperatures. Incorporating Anti-coincidence shield data (which served as a surrogate for the background) was also found to improve the analysis. We used these influential parameters to estimate the background during the Crab observation.We present the technique and resulting background estimate using the PCA approach.

109.82 — Balloon flight of the Advanced Scintillator Compton Telescope (ASCOT)

Tejaswita Sharma[1]*; Peter F. Bloser*[1,2]*; Jason Legere*[1]*; Christopher Bancroft*[1]*; Colin Frost*[1]*; Mark L. McConnell*[1,3]*; James M. Ryan*[1]*; Alex M. Wright*[1]

[1] University of New Hampshire (Durham, New Hampshire, United States)

[2] Los Alamos National Laboratory (Los Alamos, New Mexico, United States)

[3] Southwest Research Institute, Dept. of Earth, Oceans and Space (Durham, New Hampshire, United States)

The Advanced Scintillator Compton Telescope (ASCOT) is a new medium-energy gamma-ray Compton telescope addressing the existing need for a mission in the medium-energy gamma-ray energy range of 0.4 - 20 MeV. ASCOT is a prototype built on the legacy of COMPTEL instrument onboard CGRO. It uses commercially available high-performance scintillators, such as Cerium Bromide (CeBr3) and p-terphenyl in conjunction with Silicon Photomultipliers (SiPM) which are compact readout devices to improve the instrument response. Together with these advancements in hardware, ASCOT also uses the Time-of-Flight background rejection, an important tool for effective imaging in this energy range. ASCOT was developed with the goal of imaging the Crab Nebula at MeV energies during a high-altitude balloon flight. The balloon payload was launched by

NASA from Palestine (TX) on 5th July 2018. It was a successful flight with ASCOT operating stably and observing the Crab for ~5 hours from an altitude of 120,000 ft. We present here the development of the instrument and a preliminary look at the flight data. Pre-flight calibrations and simulations results are also shown, based on which we expect a ~4.5 sigma detection of the Crab in the 0.2 - 2 MeV band. The results from ASCOT will be pivotal in demonstrating an improvement in the energy, timing, and position resolution using this advanced technology.

109.83 — 511-keV All-Sky Imaging with COSI

Andreas Zoglauer[1]; Carolyn Kierans[2]; Jacqueline Beechert[1]; Steve Boggs[3,1]; T. J. Brandt[2]; Hadar Lazar[1]; Jarred Matthew Roberts[3]; John Tomsick[1]

[1] *Space Sciences Laboratory, UC Berkeley (Berkeley, California, United States)*

[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

[3] *UC San Diego (San Diego, California, United States)*

COSI, the Compton Spectrometer and Imager, is a balloon-borne gamma-ray telescope which operates in the 0.2 to 5 MeV energy range and utilities 12 high-purity Germanium double-sided strip detectors for gamma-ray detection. In spring 2016, COSI had a very successful 46-day balloon flight from Wanaka, New Zealand using NASA's new super-pressure balloon platform which took COSI 1.5 times around the world. During the flight, COSI observed gamma-ray bursts, compact objects, the Galactic 511-keV annihilation emission, Galactic nucleosynthesis, and relativistic electron precipitation events. All-sky Compton imaging is one of the most challenging data-analysis tasks for a modern, all-sky-scanning Compton telescope. For COSI, the imaging approach needs to take into account the response of the detector as a function of energy and field-of-view position, the varying background levels throughout the balloon flight, and the varying atmospheric column density above the instrument as a function of incidence angle. Another challenge is the high- dimensional response of a Compton telescope (COSI: 5 to 8), which needs to be generated by simulations on supercomputers (COSI: cori/NERSC). Finally, the image reconstruction itself can only be performed via iterative image deconvolution approaches such as Richardson-Lucy or Maximum-Entropy. For COSI, the easiest example to test our imaging approach is the 511-keV emission from the Galactic Center and Galactic bulge region. In this presentation, we will show the latest 511-keV all-sky images as observed during the COSI 2016 balloon flight, reconstructed with different response representations and image reconstruction approaches (Richardson-Lucy, Maximum-Entropy & Likelihood ratio).

109.84 — A radical new era for transient astrophysics with Swift

Jamie Kennea[1]; Brad Cenko[2]

[1] *Department of Astronomy and Astrophysics, Penn State (University Park, Pennsylvania, United States)*

[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

We have entered a new era of multi-messenger astronomy, with the recent detections of both EM counterparts of Gravitational Wave sources (GW170817), and the IceCube detection of possible neutrino from the blazar TXS 0506+056. In both these discoveries, NASA's Neil Gehrels Swift Observatory provided unique measurements, thanks to its rapid response capabilities, its fast slewing, and its agile operations team. Swift has unique advantages over other telescopes, its multi-wavelength capabilities, its location in space means it can be on target quicker than ground based telescopes which may have to wait for the Sun to set, and in addition Swift is the only X-ray and UV telescope capable of tiling large areas of the sky needed to search for transients with poor localizations, a capability currently only in the proposal stage for other space based telescopes. We discuss how Swift's response to discoveries by other telescopes, including MAXI, IceCube, ALIGO/AVirgo, ZTF, ASAS-SN and IPN has evolved to meet an ever increasing demand for rapid observations, over larger and more complex regions of the sky. We will present recent science results from Swift highlighting these capabilities. Finally we present what's next for Swift: new developments that will allow Swift to respond quicker, observe more targets, and observe larger and more complex error regions, turning Swift into a discovery tool for multi-messenger EM counterparts, and putting Swift at the forefront of transient astrophysics.

109.85 — The X/Gamma-rays Imaging Spectrometer (XGIS) on-board THESEUS

Lorenzo Amati[1]; Claudio Labanti[1]

[1] *INAF - OAS Bologna (Bologna, BO, Italy)*

The Transient High-Energy Sky and Early Universe Surveyor (THESEUS) mission concpet, aimed at fully exploiting the large potentialities of GRB for cosmology and providing a substantial contribution to time-domain and multi- messenger astrophysics, currently under Phase A study by ESA as candidate M5 mission, includes a compact and modular X and gamma-ray imaging spectrometer (XGIS). The XGIS will be a GRB and X/gamma-rays transient monitor providing an unprecedented combination of energy band (2 keV - 20 MeV), field of view (at least 2sr up to 150 keV and open at higher energies), energy resolution (300 eV in 2–30 keV), ans source lcoaiton accuracy (5 arcmin in the 2-30 keV energy band). The experiment envisages the use of CsI scintillator bars read out at both ends by single-cell 25 mm2 Silicon Drift Detectors. Events absorbed in the Silicon layer (lower energy X rays) and events absorbed in the scintillator crystal (higher energy X rays and gamma -rays) are discriminated using the on-board electronics. A coded mask provides imaging capabilities at low energies, thus allowing a compact and sensitive instrument in a wide energy band. . The instrument design, expected performance and the characterization performed on a series of laboratory prototypes are discussed.

109.87 — The Soft X-ray Imager on THESEUS — the Transient High Energy Survey and Early Universe Surveyor

P. O'Brien[1]
[1] *Department of Physics and Astronomy, University of Leicester (Leicester, United Kingdom)*

We are entering a new era for high energy astrophysics with the use of new technology to increase our ability to both survey and monitor the sky. I will present the Soft X-ray Imager instrument on THESEUS, which is under Phase A study by ESA for its M5 mission. THESEUS will carry two large area monitors utilising Lobster-eye (the SXI instrument) and coded-mask (the XGIS instrument) technologies and an optical-IR telescope to provide redshift estimates using imaging and spectroscopy. This combination, on a rapid response spacecraft, will locate and characterise many hundreds of GRBs and other transients per year. The SXI will operate in the soft X-ray band, imaging about a steradian instantaneously with arcminute localisation accuracy. It will find thousands of transients facilitating an exploration of the earliest phase of star formation and comes at a time when multi-messenger astronomy has begun to provide a new window on the universe. THESEUS will also provide key targets for other observing facilities, such as Athena and 30m class ground-based telescopes.

110 — Multi-Messenger Astrophysics Poster Session

110.01 — Low-Latency Algorithm for Multi-messenger Astrophysics (LLAMA) with Gravitational-Wave and High-Energy Neutrino Candidates

Stefan Trklja Countryman[1]*; Azadeh Keivani*[1]*; Imre Bartos*[2]*; Zsuzsa Marka*[1]*; Thomas Kintscher*[3]*; K. Rainer Corley*[1]*; Erik Blaufuss*[4]*; Chad Finley*[5]*; Szabolcs Marka*[1]
[1] *Department of Physics, Columbia University (Brooklyn, New York, United States)*
[2] *University of Florida, Gainesville (Gainesville, Florida, United States)*
[3] *DESY (Zeuthen, Brandenburg, Germany)*
[4] *University of Maryland, College Park (College Park, Maryland, United States)*
[5] *Stockholm University (Stockholm, Sweden)*

We describe in detail the online data analysis pipeline that was used in the multi-messenger search for common sources of gravitational waves (GWs) and high-energy neutrinos (HENs) during the second observing period (O2) of Advanced LIGO and Advanced Virgo. Beyond providing added scientific insight into source events, low-latency coincident HENs can offer better localization than GWs alone, allowing for faster electromagnetic follow-up. Transitioning GW+HEN analyses to low-latency, automated pipelines is therefore mission-critical for future multi-messenger efforts. The O2 Low-Latency Algorithm for Multi-messenger Astrophysics (LLAMA) also served as a proof-of-concept for future online GW+HEN searches and led to a codebase that can handle other messengers as well. During O2, the pipeline was used to take LIGO/Virgo GW candidates as triggers and search in realtime for temporally coincident HEN candidates provided by the IceCube Collaboration that fell within the 90% confidence region of the reconstructed GW skymaps. The algorithm used NASA's Gamma-ray Coordinates Network to report coincident alerts to LIGO/Virgo's electromagnetic follow-up partners.

110.02 — Prospects for Multimessenger Astrophysics with Networks of Future Gravitational-Wave Detectors

Shreya Anand[1]*; Evan Hall*[2]*; Samaya Nissanke*[3]
[1] *California Institute of Technology (Pasadena, California, United States)*
[2] *Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*

[3] University of Amsterdam (Amsterdam, Netherlands)

While the first multi-messenger detection of a binary neutron star (BNS) has revolutionized transient astronomy, it has also help define concrete science goals with regard to understanding the nature of BNS and their host environments. As the planned upgrade to our present gravitational wave (GW) detectors approaches, we must assess whether or not these goals will be achievable using future generations of detectors. Here, we present a comparative study between results from a Fisher Matrix analysis method and a rapid Bayesian parameter estimation code (ligo.skymap) to estimate the sensitivity of 2nd generation (two Advanced LIGO detectors, Advanced Virgo, KAGRA, LIGO-India), 3rd generation (Voyager, Einstein Telescope, Cosmic Explorer) and heterogeneous detector networks to BNS, and the fraction of detections for which coincident electromagnetic counterpart detection is plausible. We report quantitative estimates of the localization ability, event detection rate, average distances, and distance uncertainties for each network configuration. Our results indicate that the number of BNS mergers detected by 3G networks will of greater number and at higher redshifts than can be followed up by our present optical telescopes. Further, we estimate that > 100 BNS will be detected within z~0.2 and with localization uncertainties of < 100 deg^2 using networks of these future detectors. Our study could be used as a strong incentive for improving the cadence, sensitivity, and detection strategy of future optical observatories for coincident GW- kilonova and short GRB afterglow detection.

110.03 — Seeking Multimessenger High-Energy Neutrino + Fermi Gamma-ray Transients: Archival Analysis Results and Real-Time Alert Prospects

Colin French Turley[1]; *Derek Brindley Fox*[1]
[1] Pennsylvania State University (State College, Pennsylvania, United States)

We have been seeking to identify individual sources or subthreshold source populations of high-energy neutrino + gamma-ray ("nu+gamma") emitting transients by coincidence analysis of Fermi LAT gamma-ray and high-energy neutrino datasets. Our analysis has the potential to detect either individual nu+gamma transient sources (durations less than 1000~s), if they exhibit sufficient gamma-ray or neutrino multiplicity, or a statistical excess of nu+gamma transients of individually lower multiplicities. I will present on our initial analysis of IceCube + Fermi LAT data and the followup analysis of ANTARES + Fermi LAT data. Although we identify no single high-confidence transients nor evidence of a subthreshold source population, we do find a possible correlation between IceCube (59-string) neutrino positions and persistently bright portions of the Fermi LAT sky; we plan to explore this possible correlation in future work. We have since extended and applied our approach to the full 8-year ANTARES neutrino dataset, and have begun implementation and deployment of the first real-time nu+gamma (candidate) transient alerts via the Astrophysical Multimessenger Observatory Network (AMON). Monte Carlo simulations confirm that our alerts are capable of triggering on single-neutrino (ANTARES or IceCube) coincidences with high- multiplicity Fermi LAT sources, including LAT-detected gamma-ray bursts. I will present the latest results of these archival and real-time multi-messenger transient searches.

110.04 — Modeling the Relativistic Jet of GW170817

Brian Morsony[1]; *Davide Lazzati*[2]; *Rosalba Perna*[3]
[1] Department of Physics, California State University Stanislaus (Turlock, California, United States)
[2] Oregon State University (Corvallis, Oregon, United States)
[3] Stony Brook University (Stony Brook, New York, United States)

We model GW170817 as the emission of an off-axis relativistic jet. The jet used for our model was produced by a single hydrodynamics simulation of a short GRB, producing a structured jet that is energetic in the center and falls off at larger angles. We find that the prompt gamma-ray emission, late- time X-ray and radio afterglow, and observed superluminal motion of the radio source are all consistent with GW170817 being a typical short GRB seen off- axis.

110.05 — The multi-messenger program of the VERITAS gamma-ray observatory

Marcos Santander[1]
[1] University of Alabama (Tuscaloosa, Alabama, United States)

VERITAS, an array of atmospheric Cherenkov telescopes sensitive to gamma rays in the very high energy range (VHE, E > 100 GeV), carries out an extensive multi-messenger program focused on the search for electromagnetic counterparts to high-energy neutrinos and gravitational waves. As both neutrinos and gamma rays are expected to be produced in hadronic interactions near cosmic-ray accelerators, the detection of a gamma-ray source in temporal and spatial coincidence with astrophysical neutrinos could reveal cosmic-ray sources and provide insights into their properties. The detection of gravitational waves by LIGO in coincidence with a gamma-ray burst has opened exciting possibilities for the study of these powerful transients, and the detection of VHE gamma rays from these sources would not only help in pinpointing an electromagnetic counterpart to the gravitational wave event but also enable the study of the relativistic shocks responsible for the high- energy emission. This talk will present an overview of the VERITAS multi- messenger program highlighting recent results from the search of VHE gamma-ray sources associated with neutrino and gravitational wave events and discuss future plans for these studies.

110.06 — High Energy Astronomy Phenomena Featured Recently on APOD

Robert Nemiroff[1]; Jerry Bonnell[2]
[1] Department of Physics, Michigan Technological University (Houghton, Michigan, United States)
[2] University of Maryland (College Park, Maryland, United States)

The Astronomy Picture of the Day site (APOD: main URL: https://apod.nasa.gov/) regularly features discovery-inspired and educationally-oriented images from high energy astronomy missions. Within the 2018 calendar year, for example, APOD has featured results from Chandra, Fermi, GALEX, SDO, SOHO, and XMM-Newton. Results were also mentioned from AGILE, HAWC, HESS, INTEGRAL, MAGIC, NuSTAR, Swift, and VERITAS. Over the past year, APOD has highlighted high energy emission from AGN, black holes, galaxy clusters, galaxy collisions, Herbig-Haro Objects, Jupiter, neutron stars, planetary nebulae, pulsars, star forming regions, Sun, Sgr A*, supernova remnants, Wolf-Rayet stars, and the early universe (IllustrisTNG simulation). In 2018, APOD's log files typically recorded over 800K page views each day, exclusive of social media pages which combined have over 2M followers. APOD has been updated daily since 1995. An assortment of APODs from 2018 highlighting high energy emission are presented.

111 — NICER Poster Session

111.01 — Spectral and timing evolution of the black hole transient MAXI J1727-203 with NICER

Kevin Alabarta[1,2]; Diego Altamirano[1]; Mariano Mendez[2]; Virginia Cúneo[3]; Ronald Remillard[4]; Jeroen Homan[5,6]; Phil Uttley[7]; Renee Ludlam[8]; Keith Gendreau[9]; Zaven Arzoumanian[9]
[1] School of Physics and Astronomy, University of Southampton (Southampton, United Kingdom)
[2] Kapteyn Astronomical Institute (Groningen, Netherlands)
[3] Instituto Argentino de Radioastronomia (Berazategui, Prov. de Buenos Aires, Argentina)
[4] MIT Kavli Institute for Astrophysics and Space Research (Cambridge, Massachusetts, United States)
[5] Eureka Scientific (Oakland, California, United States)
[6] SRON, Netherlands Institute for Space Research (Utrecht, Netherlands)
[7] Anton Pannekoek Institute for Astronomy (Amsterdam, Netherlands)
[8] University of Michigan (Ann Arbor, Michigan, United States)
[9] Astrophysics Science Division, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)

MAXI J1727-203 is a new X-ray transient discovered on 5 June 2018. A hard- to-soft state transition at the beginning of the outburst led to the identification as a black hole candidate. MAXI J1727-203 was monitored with the Neutron Star Interior Composition Explorer (NICER) on an almost daily basis from the beginning of the outburst. We present a spectral and timing analysis of the full outburst of the source, which lasted approximately four months. A preliminary spectral analysis suggest that the accretion disk component can was detected throughout the entire outburst, with temperatures ranging from ∼0.4 keV (in the soft state), down to ∼0.2 keV near the end of the outburst when the source was in the hard state. The power spectrum in the hard state shows broadband noise up to 10 Hz, with no detection of any quasi- periodic oscillations. We argue that the system's characteristics are not consistent with those expected for a neutron star and that they are particularly reminiscent of the black hole X-ray binaries XTE J1118+480 and Cyg X-1.

111.02 — Nicer and AstroSat Observations of Swift J1658.2-4242 during its 2017 Outburst

Aru Beri[1,2]; Diego Altamirano[2]; Ron Remillard[3]; James F. Steiner[3]; Zaven Arzoumanian[4]; Keith Arnaud[4]; Jeroen Homan[5,6]
[1] Department of Physics, IISER Mohali (Mohali, India)
[2] University of Southampton (Southampton, United Kingdom)
[3] MIT (Cambridge, Massachusetts, United States)
[4] NASA (Greenbelt, MD, Washington, United States)
[5] Eureka Scientific (Oakland, California, United States)
[6] SRON (Utrecht, Netherlands)

Swift J1658.2-4242 (J1658) is an X-ray transient discovered in 2017. During its only outburst seen so far, J1658 was regularly monitored with the Neutron star Interior Composition Explorer (NICER). Based on the radio/X-ray properties and an assumed distance (> 3 kpc) it was classified as a black hole candidate. We present preliminary results of the spectral and timing characteristics as measured with NICER. The spectral decomposition shows a significant thermal contribution in the form of blackbody emission, in addition to a thermal disk component, which is not expected for a black hole low-mass X-ray binary. We also present the results of a long AstroSat observation made at the beginning of the outburst. The data obtained with the Large Area X-ray Proportional Counter (LAXPC) on board AstroSat revealed the presence of a strong and sharp QPO at around 2.4 Hz. The energy-dependent time-lag spectrum shows a soft lag (soft photons trail behind hard photons) at the QPO frequency, where the fractional rms of the QPO increases with photon energy. We show that our comprehensive spectral study in the 0.4-12 keV band using all the observations made with NICER and the broadband spectra as seen by the Soft X-Ray Telescope (SXT) and LAXPC suggest that the accretor is a neutron star, rather than a black hole as suggested by previous work.

111.03 — NICER X-ray Timing of Radio and Gamma-ray Quiet Pulsars for Continuous Gravitational Wave Source Searches

Slavko Bogdanov[1]; Wynn C.G. Ho[2]; Teruaki Enoto[3]; Sebastien Guillot[4]; Alice Harding[5]; Gaurava K. Jaisawal[7]; Christian Malacaria[6]; Sridhar S. Manthripragada[5]; Zaven Arzoumanian[5]; Keith Gendreau[5]

[1] *Columbia Astrophysics Laboratory, Columbia University (New York, New York, United States)*

[2] *Haverford College (Haverford, Pennsylvania, United States)*

[3] *Kyoto University (Kyoto, Japan)*

[4] *IRAP (Toulouse, France)*

[5] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[6] *NASA Marshall Space Flight Center (Huntsville, Alabama, United States)*

[7] *Technical University of Denmark (Lyngby, Denmark)*

We present new timing and spectral analyses of PSR J1412+7922 (Calvera) and PSR J1849-0001, which are only seen as pulsars in X-rays, based on observations conducted with the Neutron Star Interior Composition Explorer (NICER). We obtain updated and substantially improved pulsar ephemerides compared to previous X-ray studies, as well as spectra that can be well-fit by simple blackbodies and/or a power law. Our refined timing measurements enable deeper searches for pulsations at other wavelengths and sensitive targeted searches by LIGO/Virgo for continuous gravitational waves from these neutron stars. Using the sensitivity of LIGO's first observing run, we estimate constraints that a gravitational wave search of these pulsars would obtain on the size of their mass deformation and fluid oscillation.

111.04 — Modeling the X-ray time lags observed by NICER in MAXI J1820+070.

Arkadip Basak[1]; Phil Uttley[1]

[1] *Department of Astronomy, University of Amsterdam (Amsterdam, Netherlands)*

Recently, Kara et al. (2019) used NICER's unprecedented bright-source spectral-timing capability to show that the energy and frequency dependent time lags seen in X-ray variations of the very bright black hole transient MAXI J1820+070 evolve significantly during the hard state, while the relativistically broadened iron line shape remains the same. These results imply a changing coronal height to explain the changing lags, rather than changing inner disk radius, but the exact physical mechanism for the lags remains unclear.

A new model we are developing (Uttley & Malzac 2019) suggests that the low-frequency 'hard' lags are a natural consequence of accretion fluctuations, which propagate through the accretion disk to modulate the disk photons which cool the corona before the fluctuations make their way into the corona itself and heat it. The model predicts that the hard lags and associated short-term 'soft' lags (driven by reverberation) are both strongly dependent on coronal geometry, which governs how far out in the disk the corona can 'see' and respond to photon fluctuations. Here we apply the model to these NICER data, to see whether it can explain the observed strong evolution in terms of evolving coronal, rather than disk, geometry.

111.05 — A NICER spectral and timing analysis of the Rapid Burster

Angel Castro[1]; Diego Altamirano[1]; Kevin Alabarta[1]; Zaven Arzoumanian[2]; Deepto Chakrabarty[3]; Ronald Remillard[3]; Keith Gendreau[2]; Yuri Cavecchi[1]; Jeroen Homan[4,5]

[1] *University of Southampton (Southampton, Hampshire, United Kingdom)*

[2] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[3] *Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*

[4] *Eurka Scientific (Oakland, California, United States)*

[5] SRON (Utrecht, Utrecht, Netherlands)

We report a spectral-timing analysis of observations of the low mass X-ray binary MXB 1730-335, also known as Rapid Burster, obtained in July 2018 with the Neutron star Interior Composition Explorer (NICER). The Rapid Burster is the only object known to show both quickly repetitive type-II X-ray bursts, believed to be caused by instabilities in the accretion process, and type-I bursts, associated with thermonuclear burning. Its NICER 0.2-10 keV light curve shows the presence of several typical type-II bursts with different duration and one candidate thermonuclear type-I burst. The timing resolution and low-energy coverage of NICER allow us to perform time-resolved spectroscopy for some of the bursts. A preliminary analysis indicates the presence of a varying soft component, which implies that the type-II burst spectra change as the bursts evolve. This is the first time such a soft component is detected in type II bursts, suggesting that these bursts could be the result of limit cycles similar to those identified in the black hole systems GRS 1915+105 and IGR J17091-3624.

111.06 — NICER X-ray Spectrometry of the Massive Colliding Wind Binary WR140 after Periastron Passage

Michael Corcoran[1,2]
[1] *CRESST2, NASA/GSFC, The Catholic University of America (Crofton, Maryland, United States)*
[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

WR 140 is a long-period (P_{orb} = 7.9 years), massive, highly eccentric (e $\sim$ 0.9) evolved colliding wind binary system consisting of a carbon-rich WC7 star and an O5.5fc companion star with well-determined stellar parameters and orbital elements. WR 140 rose to astrophysical prominence on the basis of its extraordinary X-ray luminosity and strongly variable IR emission (both of which peak near periastron passage when density in the wind-wind shock region increases and when strong compression causes the formation of dust). As such, this binary system serves as a unique cosmic laboratory for understanding astrophysical shocks with time-varying densities and cooling rates, the process of dust formation, and how massive stars lose mass and how they reshape and chemically enrich their circumstellar environments prior to the supernova explosion. We present time-resolved X-ray spectrometry of WR 140 with NICER in the months following the most recent periastron passage in December 2016. We compare the NICER spectral parameters with X-ray monitoring observations with RXTE and Swift. The NICER spectra show an extended interval of enhanced X-ray absorption following periastron passage. We find that the temporal behavior of the X-ray wind absorption is similar to the on-going decline in K-band brightness, suggesting a connection between the expansion and cooling of the dust shell and the emergence of the inner colliding wind shock as the stars separate.

111.07 — NICER look at the low-luminosity state transitions seen in MAXI J1535-571

Virginia Cúneo[1]*; Kevin Alabarta*[2]*; Diego Altamirano*[2]*; Ronald Remillard*[3]*; Jeroen Homan*[4,5]*; Jorge Combi*[1]*; Keith Gendreau*[6]*; Zaven Arzoumanian*[6]
[1] *Instituto Argentino de Radioastronomía (Villa Elisa, Buenos Aires, Argentina)*
[2] *University of Southampton (Southampton, Hampshire, United Kingdom)*
[3] *MIT (Cambridge, Massachusetts, United States)*
[4] *Eureka Scientific (Oakland, California, United States)*
[5] *SRON (Utrecht, Utrecht, Netherlands)*
[6] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The black hole candidate and X-ray binary MAXI J1535-571 was discovered in September, 2017. During the declining phase of the outburst, and before returning to quiescence, MAXI 1535-571 showed 4 reflares, similar to those seen in CVs (and known as echo outbursts). To investigate the nature of these flares, NICER sampled them with almost daily cadence. We present preliminary results on the spectral and timing evolution of the 4 reflares. The higher sensitivity of NICER at lower energies, in comparison with other X-ray detectors, allowed us to constrain the 0.2-0.3 keV disk component of the spectrum. We found that during each reflare, the source appears to trace out a q-shaped track similar to those which BHs usually trace out during full outbursts. However, MAXI J1535-571 does not return to the soft state during these flares, but transits between hard and intermediate states. We discuss the implications of our results.

111.08 — Swift and NICER observations of the X-ray binary GX 301-2 during the X-Calibur balloon campaign in December 2018.

Manel Errando[1]*; Logan Press*[1]*; Henric Krawczynski*[1]*; Quin Abarr*[1]*; Richard Bose*[1]*; Dana Braun*[1]*; Gianluigi De Geronimo*[2]*; Paul Dowkontt*[1]*; Thomas Gadson*[3]*; Victor Guarino*[1]*; Scott Heatwole*[3]*; Nirmal Iyer*[4]*; Fabian Kislat*[5]*; Mózsi Kiss*[4]*; Takao Kitaguchi*[6]*; Rakhee*

Kushwah[4]; James Lanzi[3]; Shaorui Li[7]; Lindsey Lisalda[1]; Takashi Okajima[8]; Mark Pearce[4]; Zachary Peterson[3]; Brian Rauch[1]; David Stuchlik[3]; Hiromitsu Takahashi[9]; Jason Tang[1]; Nagomi Uchida[9]; Andrew West[1]

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

[2] *Stpny Brook (NY, New York, United States)*

[3] *Wallops Flight Center (Wallops Island, Virginia, United States)*

[4] *KTH (Stockholm, Sweden)*

[5] *UNH (NH, New Hampshire, United States)*

[6] *RIKEN (JP, Japan)*

[7] *BNL (NY, New York, United States)*

[8] *GSFC (Bethesda, Maryland, United States)*

[9] *Hiroshima University (Hiroshima, Japan)*

The X-Calibur hard X-ray polarimeter mission was launched in December 29th 2018 from McMurdo station in Antarctica and completed a 2-day duration balloon flight. During the campaign, X-Calibur observed the high-mass X-ray binary GX 301-2 in a high-flux state. GX 301-2 is composed of a neutron star accreting from a B-1-type stellar companion. The X-ray signal is modulated by the system's orbital period of ~41 days. Pulsations linked to the spin of the neutron star are also observed with a ~680 s period. We present results from Swift-XRT and NICER observations of GX 301-2 in the soft X-ray band obtained before, during, and after the X-Calibur flight. Swift provided daily monitoring between 2018-12-28 and 2019-01-05. Observations covered the preperiastron flare of GX 301-2, showing a flux variation of a factor of ~3 peaking at $(3.6\pm0.2)\times10^{-9}$ erg cm^{-2} s^{-1} (2-10 keV) on 2019-01-01. NICER collected data on 2018-12-28 and 29, including one continuous 1 ks exposure that covers one full pulsar period. The spectra collected show a heavily absorbed power law spectrum with prominent Fe K-alpha fluorescent line emission. The flux, spectral, and column density evolution of the X-ray emission of GX 301-2 will be presented and discussed in conjunction with the X-Calibur results on the source.

111.09 — Searching for thermally-emitting millisecond pulsars with NICER

Sebastien Guillot[1]; Matthew Kerr[2]; Paul S. Ray[2]; Scott Ransom[3]; Slavko Bogdanov[4]; Keith Gendreau[5]; Zaven Arzoumanian[5]; Julia Deneva[2]; Mike Wolff[2]; Christian Malacaria[6]

[1] *IRAP (Toulouse Cedex 4, France)*

[2] *NRL (Washington, District of Columbia, United States)*

[3] *NRAO (Charlottesville, Virginia, United States)*

[4] *Columbia University (New York, New York, United States)*

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

[6] *NASA Marshall (Huntsville, Alabama, United States)*

The Neutron Star Interior Composition Explorer (NICER) has been in operation on the International Space Station since June 2017. One of its key science goals is the search for X-ray modulations from a variety of neutron star classes. To achieve this, NICER offers new capabilities in the soft X-ray band, namely, high effective area, precise timing (~100 nsec), and flexible scheduling. The working group on Pulsation Searches and Multi-wavelength Coordination had prepared a list of a few tens of sources to observe, for a total of 2.5 Ms. Among them were known millisecond radio pulsars with no detected pulsations in the X-ray band, sometimes with evidence of thermal emission from spectral analyses. Finding more thermally-emitting millisecond pulsars with a range of masses and radii is key to obtaining constraints on the dense matter equation of state via modelling of each neutron star's pulse profile. On behalf of this working group, I will present the results of these pulsation searches of millisecond pulsars with suspected surface thermal emission.

111.10 — NICER Observations of the Thermal Emission from PSR B0656+14

Alice Harding[1]; Teruaki Enoto[2]; Shogo Kobayaashi[9]; Lucas Guillemot[3]; Wynn C.G. Ho[4]; Tolga Guver[5]; Sebastien Guillot[6]; Christian Malacaria[1]; Ronald Remillard[7]; Michael Loewenstein[1]; Paul S. Ray[8]; Andrew Aylward[1]; Zaven Arzoumanian[1]; Keith Gendreau[1]

[1] *Astrophysics Science Division, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[2] *Kyoto University (Kyoto, Japan, Japan)*

[3] *University of Orleans (Orleans, France, France)*

[4] *Haverford College (Haverford, Pennsylvania, United States)*

[5] *University of Istanbul (Istanbul, Turkey, Turkey)*

[6] *Institut de Recherche en Astrophysique et Planétologie (IRAP - CNRS) (Toulouse, France, France)*

[7] *Massachusetts of Technology (Cambridge, Massachusetts, United States)*

[8] *Naval Research Laboratory (Washington, District of Columbia, United States)*

[9] *Tokyo University of Science (Tokyo, Japan, Japan)*

PSR B0656+14 is a middle-aged rotation-powered pulsar and a member of the "Three Musketeers," which also includes Geminga and PSR B1055-52. These pulsars show complex, multi-component pulsed X-ray emission best fit with two thermal spectra plus a power law. PSR B0656+14 has been extensively observed by NICER since its launch in 2017, obtaining precise dependence of spectral features with pulse phase. The NICER data show three distinct hot spots that cover different energy bands and

rotational phases - a cool thermal radiation component from the entire neutron star surface, a smaller hot spot presumably from polar cap heating, and a more mysterious "spot" of intermediate temperature. We see that the X-ray emission peaks from these hot spots occur at different rotation phases, that are also different from the phases of the radio and gamma-ray peaks. The complex variation of temperature across the surface possibly suggests evolution of multipolar magnetic field structure.

111.11 — Highlights from NICER's coverage of the black hole transient MAXI J1820+070

Jeroen Homan[1,2]; Ronald Remillard[3]; James F. Steiner[3]; Joseph Neilsen[5]; Keith Gendreau[4]; Zaven Arzoumanian[4]; Andrew Fabian[6]; Erin Kara[7]; Diego Altamirano[8]; Phil Uttley[9]; Abigail Stevens[12]; Sara Motta[10]; Rob Fender[10]; James Miller-Jones[11]; Joe Bright[10]; David Williams[10]

[1] *Eureka Scientific (Boston, Massachusetts, United States)*
[2] *University of Oxford (Oxford, United Kingdom)*
[3] *Curtin University (Perth, Western Australia, Australia)*
[4] *Michigan State University (East Lansing, Michigan, United States)*
[5] *SRON (Utrecht, Netherlands)*
[6] *MIT (Cambridge, Massachusetts, United States)*
[7] *NASA/GSFC (Greenbelt, Maryland, United States)*
[8] *Villanova (Radnor, Pennsylvania, United States)*
[9] *University of Cambridge (Cambridge, United Kingdom)*
[10] *University of Maryland (College Park, Maryland, United States)*
[11] *University of Southampton (Southampton, United Kingdom)*
[12] *University of Amsterdam (Amsterdam, Netherlands)*

MAXI J1820+070 is a relatively nearby (3 kpc) black hole transient that showed an exceptionally bright outburst in 2018 that lasted for more than 250 days. This outburst was observed in great detail by NICER, with more than 700 individual pointings covering nearly six orders of magnitude in flux. The NICER data set of MAXI J1820+070 is one of the richest data sets for any black hole transient. Here we briefly present two of the main highlights from our ongoing analysis. The first result concerns the presence of a warm absorber during the fast rising phase of the outburst. From semi-regular dips in the light curve we infer that this absorbing structure is located at a few thousand gravitational radii from the black hole and has a large vertical extent. We suggest that its origin may be related to the disk not being able to handle the sudden increase in accretion rate. The second result concerns a rapid (few days) state transition near the peak of the outburst. Unprecedented monitoring with NICER enabled us to follow the evolution of the source in near real-time during this transition. Combined with high-quality coverage of a radio flare that occurred around the time of the transition, the NICER data allowed to address the question of whether or not a relatively rare type of low-frequency QPO is connected to the launch of transient radio jets in black hole X-ray binaries.

111.12 — A joint *NICER* and *XMM-Newton* view of the "Magnificent" thermally emitting X-ray Isolated Neutron Star RX J1605.3+3249

Christian Malacaria[1,12]; Slavko Bogdanov[2]; Wynn C.G. Ho[3,4]; Teruaki Enoto[5]; Paul S. Ray[6]; Zaven Arzoumanian[7]; Thoniel Cazeau[7]; Keith Gendreau[7]; Sebastien Guillot[8]; Tolga Guver[9,10]; Gaurava K. Jaisawal[11]; Mike Wolff[6]

[1] *NASA Marshall Space Flight Center, NSSTC, (Huntsville, Alabama, United States)*
[2] *Istanbul University Observatory Research and Application Center, Beyazit (Istanbul, Turkey)*
[3] *National Space Institute, Technical University of Denmark, Elektrove (Lyngby, Denmark)*
[4] *Universities Space Research Association, NSSTC (Huntsville, Alabama, United States)*
[5] *Columbia Astrophysics Laboratory, (New York, New York, United States)*
[6] *Department of Physics and Astronomy, Haverford College (Haverford, Pennsylvania, United States)*
[7] *Mathematical Sciences, Physics and Astronomy, and STAG Research Centre, University of Southampton (Southampton, United Kingdom)*
[8] *Department of Astronomy, Kyoto University (Kyoto, Japan)*
[9] *Space Science Division, U. S. Naval Research Laboratory (Washington, District of Columbia, United States)*
[10] *X-ray Astrophysics Laboratory, Astrophysics Science Division, NASA's Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[11] *CNRS, IRAP (Tolouse, France)*
[12] *Department of Astronomy and Space Sciences, Science Faculty, Istanbul University (Istanbul, Turkey)*

X-ray thermally emitting Isolated Neutron Stars represent excellent targets to test cooling surface emission or atmospheric models, and therefore derive physical parameters of the neutron star. Among the seven known members of this class, RX J1605.3+3249 is the only one that still lacks a confirmation for a pulsating signal. Here we analyze NICER and XMM-Newton dedicated observations of RX J1605.3+3249 in order to address its timing and spectral behavior. Contrary to what tentatively proposed in previous works, we found no significant pulsation with pulsed fraction higher than 1.3% (3 sigma), in spite of attempts performed at different energy bands. This is likely due either to unfavorable geometrical effects or to isotropic atmospheric emission. The X-ray spectrum can be fit either by a double-blackbody model or a magnetized atmospheric model, both modified by a Gaussian absorption line at 0.44 keV. The origin of the absorption feature as a proton cyclotron line or as molecular transition in the neutron star atmosphere will be illustrated. The predictions of the best-fit X-ray models extended to the optical/UV band are compared with archival data and reveal that the nominal double-blackbody model is consistent with the optical data. The predictions of the best-fit X-ray models extended to the optical/UV band are compared with archival data and reveal that the nominal double-blackbody model is consistent with data in the optical band. This result is of interest because it removes the need for additional components such as those used in previous works to fit optical data from this source. Instead, a UV excess is predicted in some cases, possibly due to absorption from a dusty environment surrounding the compact object.

111.13 — The Neutron Star Interior Composition Explorer (NICER): Calibration Status

Craig Bishop Markwardt[1]; Keith Gendreau[1]; Zaven Arzoumanian[1]; Takashi Okajima[1]; James F. Steiner[2]; Gregory Prigozhin[2]; Ronald Remillard[2]; Teruaki Enoto[3]

[1] *Code 662, NASA/GSFC (Greenbelt, Maryland, United States)*
[2] *MIT Kavli Institute (Cambridge, Massachusetts, United States)*
[3] *Kyoto Univ. (Kyoto, Japan)*

NASA's Neutron star Interior Composition Explorer (NICER) is an X-ray observatory launched and installed on the International Space Station in June 2017. After a month of commissioning, NICER began pointed science observations of neutron star and other astrophysical X-ray emitters. NICER contains 52 operating X-ray telescopes, each composed of an X-ray concentrator optic and a single-pixel silicon drift detector at the focal plane. The total effective area is >1900 cm^2 at 1.5 keV. Each module is capable of silicon CCD-like resolution, but with high throughput and nanosecond-level timestamping capabilities. We describe the current status of NICER's X-ray Timing Instrument, such as the photon energy resolution and time-stamping accuracy, as well as inflight effective collecting area, pointing, background, and other calibration efforts. The payload meets all of its design requirements and is poised to deliver new insights in soft X-ray astrophysics.

111.14 — NICER Observations of Cygnus X-3 During a Period of Gamma-Ray Activity

Michael L. McCollough[1]; Michael Corcoran[2]; Abigail Stevens[3]; Timothy Kallman[4]; Dheeraj Pasham[5]; Karri Koljonen[6]; Tod Strohmayer[4]; Keith Gendreau[4]; Zaven Arzoumanian[4]; Thomas Maccarone[7]; Ronald Remillard[8]; Mark Gurwell[1]; Guy Pooley[9]; David Green[9]; Sergei Trushkin[10]; Marco Tavani[11]; Giovanni Piano[11]

[1] *HEA, CfA (Cambridge, Massachusetts, United States)*
[2] *SAO/RAS (Zelenchukskaya, Karachay-Cherkessia, Russian Federation)*
[3] *IAPS/INAF (Rome, Italy)*
[4] *The Catholic University of America (Washington, District of Columbia, United States)*
[5] *Michigan State University (East Lansing, Michigan, United States)*
[6] *GSFC/NASA (Greenbelt, Maryland, United States)*
[7] *MIT (Cambridge, Massachusetts, United States)*
[8] *FINCA (Helsinki, Finland)*
[9] *Texas Tech University (Lubbock, Texas, United States)*
[10] *MIT Kavli (Cambridge, Massachusetts, United States)*
[11] *MRAO (Cambridge, United Kingdom)*

In July 2018, gamma-Ray emission from Cygnus X-3 was detected by AGILE (ATel #11804). This heralded the descent of Cygnus X-3 into a quenched/hypersoft state, which marked the start of flaring activity which culminating in several radio flares in excess of 1.0 Jy. During this activity a multi-wavelength campaign was undertaken, consisting of observations in the gamma-ray, hard X-ray, X-ray, submillimeter, and radio. Throughout this campaign NICER observations were made on a near daily basis. We present an initial analysis of the line rich spectra observed by NICER and how these features vary as a function of time and Cygnus X-3 orbital phase. We will also review the evidence for the possible first detection of a high-frequency QPO (140 Hz) in Cygnus X-3 by NICER.

111.15 — RXTE Revisited — Open Questions in Black Hole Timing for the Age of Astrosat and NICER

Michael Allen Nowak[1]; Joern Wilms[2]; Katja Pottschmidt[3]

[1] *Department of Physics, Washington University, St. Louis (St. Louis, Missouri, United States)*
[2] *Dr. Karl Remeis-Observatory & ECAP (Bamberg, Germany)*
[3] *Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The launch of Astrosat (late 2015) and NICER (mid-2017) has renewed our ability to perform fast X-ray timing observations with large effective areas. Although XMM and NuSTAR make important contributions to timing studies, we have not had a dedicated timing mission since the loss of the Rossi X-ray Timing Explorer in 2012. Exciting prospects for Galactic black hole candidate (BHC) studies with NICER recently have been shown via exploration of the evolution of both X-ray variability time scales and temporal lags between hard and soft X-ray variability as a BHC transient's luminosity declined after an outburst. Decreases in lag time scales and characteristic variability frequencies as the source faded, with only modest changes in spectral signatures (e.g., the broad Fe line) were argued as evidence for a vertically extended corona/jet structure shrinking as the source faded. These findings are in excellent agreement with historical results from RXTE, which were described at that time with essentially similar hypotheses as postulated for the NICER observations. With a 16 year legacy often encompassing hundreds of observations of a given BHC source over multiple transient outbursts or state changes, RXTE hinted at even more complex behaviors. Here we review a subset of the historical RXTE results for BHC, concentrating on observations of Cyg X-1 and GX 339-4. We review energy-dependent variability time lag resuls and higlight similarities to the NICER studies, but also discuss the additional complexities seen. We revisit implications of the coherence function as a measure of the degree of linear correlation between two variable processes and discuss how small deviations from unity coherence, correlated with the shape of the power spectral density, suggested a more complex phenomenology than "reverberation lags". X-ray time lags plausibly can be the sum of multiple processes, with opposite time lags, that average to a hard lag while reproducing the small observed deviations from unity coherence. NICER and Astrosat are well-poised to extend these studies and have the advantage of improved spectral capabilities compared to RXTE, especially when used in conjunction with observatories such as XMM and NuSTAR.

111.16 — Spotting the birth of compact objects using X-ray timing of fast-rising transients

Dheeraj Ranga Reddy Pasham[1]; Ronald Remillard[1]; Keith Gendreau[2]; Zaven Arzoumanian[2]; Tod Strohmayer[2]; Andrew Fabian[5]; Kent Wood[10]; Peter Bult[2]; Diego Altamirano[6]; Wynn C.G. Ho[7]; Scott Ransom[3]; Paul S. Ray[2]; Sebastien Guillot[4]; Alice Harding[2]; Phil Uttley[8]; Jon Miller[9]; James F. Steiner[1]; Matthew Kerr[10]; Jeroen Homan[11]; Deepto Chakrabarty[1]; Teruaki Enoto[12]; Edward Cackett[13]; Renee Ludlam[9]; Mike Wolff[10]; Slavko Bogdanov[14]

[1] *Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (MIT) (Cambridge, Massachusetts, United States)*

[2] *U.S. Naval Research Lab (D.C, District of Columbia, United States)*

[3] *Eureka Scientific (Oakland, California, United States)*

[4] *Kyoto University (Kyoto, Japan)*

[5] *Wayne State University (Detroit, Michigan, United States)*

[6] *Columbia University (New York, New York, United States)*

[7] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[8] *NRAO (Charlottesville, Virginia, United States)*

[9] *Institut de Recherche en Astrophysique et Planétologie (Toulouse, France)*

[10] *University of Cambridge (Cambridge, United Kingdom)*

[11] *University of Southampton (Southampton, United Kingdom)*

[12] *Stanford University (Menlo Park, California, United States)*

[13] *University of Amsterdam (Amsterdam, Netherlands)*

[14] *University of Michigan (Ann Arbor, Michigan, United States)*

Fast-rising, blue optical transients (FBOTs) are a new class of optical transients identified by optical sky surveys with high observing cadence. These are extra-galactic, off-nuclear flares that rise on less than a week timescale and fade within a month or two. Their optical spectra are blue and featureless with occasional presence of broad Hydrogen and Helium lines. Their fast evolution and featureless optical spectra suggest that they are unlike normal supernovae which evolve much slower and have characteristic optical spectra. Current theories for FBOTs include merging compact objects, newly formed compact objects in supernovae or failed supernovae, or intermediate- mass black holes disrupting low-mass stars. AT2018cow is the first FBOT discovered in real time and this facilitated unprecedented coverage across the entire electromagnetic spectrum. In spite of multi-wavelength coverage, the nature of the flare has remained a mystery. I will discuss the X-ray properties of the source and the possible detection of a highly-stable, quasi- periodic oscillation (QPO) using NICER monitoring data and its implications for a newly formed compact object in this event. I will also discuss prospects of detecting newly born compact objects using NICER in the coming years and the need for a large area timing instrument, viz., STROBE-X/ATHENA in the next decade.

111.17 — NICER Observations of the Ultraluminous X-ray Pulsar NGC 300 ULX-1

Paul S. Ray[1]; Sebastien Guillot[2]; Teruaki Enoto[3]; Wynn C.G. Ho[4,5]; Matthew Kerr[1]

[1] U.S. Naval Research Laboratory (Washington, District of Columbia, United States)
[2] IRAP - CNRS (Toulouse, France)
[3] Kyoto University (Kyoto, Japan)
[4] Haverford College (Haverford, Pennsylvania, United States)
[5] University of Southampton (Southampton, United Kingdom)

Recently, the ultraluminous X-ray source in the spiral galaxy NGC 300 was revealed to be an accretion-powered pulsar, with a spin period that is rapidly decreasing with time, from 31 seconds in 2016 December to 16 seconds at present. Since 2018 February 6, NICER has been monitoring this source. We will report on the spin evolution of this unique source, which includes the discovery of several "anti-glitches", where the rapid spin up is interrupted by sudden spindown glitches, in contrast to the usual spin-up glitches observed in radio pulsars.

NICER is a 0.2-12 keV X-ray telescope operating on the International Space Station. The NICER mission and portions of the NICER science team activities are funded by NASA.

111.18 — NICER Investigation of Fast Flares in Accreting Compact Objects

Ronald Remillard[1]; Dheeraj Pasham[1]; James F. Steiner[1]; Jeroen Homan[5]; Diego Altamirano[4]; Phil Uttley[3]; Joseph Neilsen[2]; Keith Gendreau[6]; Zaven Arzoumanian[6]
[1] Kavli Institute for Astrophysics, MIT (Cambridge, Massachusetts, United States)
[2] Villanova University (Villanova, Pennsylvania, United States)
[3] University of Amsterdam (Amsterdam, Netherlands)
[4] Southampton University (Southampton, United Kingdom)
[5] Eureka Scientific (Berkeley, California, United States)
[6] NASA Goddard (Greenbelt, Maryland, United States)

We use 1-second-binned NICER light curves (background subtracted) to identify high-contrast flares from X-ray binary systems. The flare detections are highly concentrated in six sources. We make empirical comparisons of the different types of flares, which occur during the hard states of black hole binaries GX 339-4 and MAXI J1820+080, the soft/intermediate state of Cyg X-1, the instability cycles of GRS 1915+105, the Type I and II bursts of the Rapid Burster, and the mysterious variations of Swift J1858.6-0814. Comparison tools include tracks on the Color-color / Hardness-Intensity Diagrams, subsecond structure, power-density spectra, flux distributions, and selected spectral modeling. Most of these phenomena have been observed with RXTE, but NICER's soft X-ray coverage enables analyses with a much better spectral view of the accretion disk.

111.19 — Fast X-ray Spectroscopy in MAXI J1820+070 with NICER

James F. Steiner[1]; Erin Kara[2]; Ronald Remillard[1]; Diego Altamirano[3]; Zaven Arzoumanian[4]; Edward Cackett[11]; Stephen Eikenberry[12]; Andrew Fabian[5]; Keith Gendreau[4]; Jeroen Homan[6]; Jon Miller[7]; Joseph Neilsen[9]; Dheeraj Pasham[1]; Abigail Stevens[8]; Phil Uttley[10]; Jakob Van Den Eijnden[10]
[1] MIT Kavli Institute (Cambridge, Massachusetts, United States)
[2] University of Amsterdam (Amsterdam, Netherlands)
[3] Wayne State University (Detroit, Michigan, United States)
[4] University of Florida (Gainesville, Florida, United States)
[5] University of Maryland (State Park, Maryland, United States)
[6] University of Southampton (Southampton, United Kingdom)
[7] NASA Goddard (Greenbelt, Maryland, United States)
[8] University of Cambridge (Cambridge, United Kingdom)
[9] Eureka Scientific (El Sobrante, California, United States)
[10] University of Michigan (Ann Arbor, Michigan, United States)
[11] Michigan State University (East Lansing, Michigan, United States)
[12] Villanova (Philadelphia, Pennsylvania, United States)

MAXI J1820+070 is one of the brightest and softest X-ray binary systems to have gone into outburst in the era of X-ray astronomy. During it's outburst last year, NICER monitored the outburst at a roughly daily cadence allowing high time fidelity monitoring of the outburst evolution. NICER's high throughput in the soft X-ray bandpass is unmatched and allows, for the first time, fast X-ray spectroscopy at the viscous timescale for the inner accretion flow.

111.20 — NICER Discovers Spectral Features During Radius Expansion Bursts from 4U 1820-30

Tod E. Strohmayer[1,2]
[1] NASA/GSFC (Greenbelt, Maryland, United States)
[2] Joint Space-Science Institute (Greenbelt, Maryland, United States)

4U 1820-30 is a well-known, ultracompact neutron star binary with an 11.4 min orbital period, and it was one of the first discovered to produce thermonuclear X-ray bursts. The system's compact nature requires a low-mass helium dwarf donor, and thus helium is likely the most abundant burst fuel. It is known that helium flashes can drive strong photospheric radius expansion (PRE), and NICER's excellent soft X-ray response is well matched to the soft thermal emission produced during such phases. NICER observed 4U 1820-30 in 2017 August during a low flux, hard spectral state, accumulating about 60 ks of exposure. Five X-ray bursts were detected of which four showed clear signs of PRE. We extracted spectra during the

PRE phases and fit each to a model that includes a comptonized component to describe the persistent emission, and a black body for the burst thermal flux. The temperature and spherical emitting radius of the fitted black body are used to assess the strength of PRE in each burst. The two strongest PRE bursts (burst pair 1) had black body temperatures of ≈0.62 keV and emitting radii of ≈97 km (at a distance of 8.4 kpc). The other bursts had higher temperatures (≈0.7 keV) and smaller radii (≈78 km, we call these burst pair 2). All of the bursts show evidence of narrow line emission near 1 keV. To improve the statistics we added the spectra of each burst pair defined above. These combined spectra both show significant features near 1 (emission), 1.7 (absorption) and 3 keV (absorption). Possible line identifications for these features are Ne X, Mg XII and S XVI. Interestingly, these are all elements that should be produced via helium burning. Remarkably, the fitted line centroids in the spectrum of pair 1 appear systematically blue-shifted by a factor of 1.045 compared to the centroids of pair 2, perhaps indicating a wind-induced blue-shift. The stronger PRE bursts (pair 1) would plausibly have the faster outflow, which is consistent with the observed shift. Assuming the lines are produced in a burst-driven wind, the energy shift between burst pairs 1 and 2 corresponds to a difference in wind outflow velocities of about 14,000 km/sec. We discuss our results in the context of recent burst-driven wind models.

111.21 — Precision X-ray Timing of HM Cnc with NICER: Probing the Evolution of the Most Compact Binary Known

Tod E. Strohmayer[1,2]

[1] *NASA/GSFC (Greenbelt, Maryland, United States)*

[2] *Joint Space-Science Institute (Greenbelt, Maryland, United States)*

HM Cnc is a double-degenerate binary with the shortest orbital period presently known. The 5.36 minute orbital period is seen as a large amplitude, soft X-ray modulation, likely from a hot-spot produced by direct impact accretion. With such a short orbital period the source is expected to have a gravitational wave luminosity comparable to or larger than that in the X-ray, and its orbital evolution should be strongly influenced by the angular momentum lost to gravitational radiation. Previous X-ray observations have shown that the orbital frequency is increasing at a rate consistent with that expected for a detached system radiating gravitational waves, however, long term accretion should eventually drive the components apart. Evolutionary calculations suggest a spin-up phase can persist past initial contact, and we may be seeing this in the X-ray timing, but a longer temporal baseline is needed to carefully test this hypothesis. We obtained NICER observations of HM Cnc in 2017 October and November, and 2018 April, extending the long-term X-ray timing baseline to more than 16 years. Combined with prior X-ray measurements, this enable a new, sensitive probe of the system's orbital evolution. NICER observations clearly detect the 5.36 minute orbital period, and the X-ray modulation profile is consistent with prior measurements. We present results of a phase timing analysis of these and earlier data that suggest the orbital spin-up may be slowing. We discuss the implications of our results for evolutionary scenarios in this and similar systems.

NICER is a 0.2-12 keV X-ray telescope operating on the International Space Station. The NICER mission and portions of the NICER science team activities are funded by NASA.

111.22 — A NICER spectral-timing study of the evolving QPO and inner region geometry in MAXI J1535-571

Phil Uttley[1]; *Adam Ingram*[2]; *Abigail Stevens*[3]; *Jakob Van Den Eijnden*[1]; *Keith Gendreau*[4]; *Zaven Arzoumanian*[4]; *Diego Altamirano*[5]; *Peter Bult*[4]; *Edward Cackett*[6]; *Andrew Fabian*[7]; *Jeroen Homan*[8,9]; *Erin Kara*[10,4]; *Jon Miller*[11]; *Ron Remillard*[12]; *James F. Steiner*[12]

[1] *University of Amsterdam (Amsterdam, Netherlands)*

[2] *University of Maryland (College Park, Maryland, United States)*

[3] *University of Michigan (Ann Arbor, Michigan, United States)*

[4] *MIT Kavli Institute for Astrophysics and Space Research (Cambridge, Massachusetts, United States)*

[5] *University of Oxford (Oxford, United Kingdom)*

[6] *Michigan State University (Lansing, Michigan, United States)*

[7] *NASA GSFC (Greenbelt, Maryland, United States)*

[8] *University of Southampton (Southampton, United Kingdom)*

[9] *Wayne State University (Detroit, Michigan, United States)*

[10] *University of Cambridge (Cambridge, United Kingdom)*

[11] *Eureka Scientific (Oakland, California, United States)*

[12] *SRON (Utrecht, Netherlands)*

In September-October 2017, NICER carried out extensive monitoring of the multi-Crab black hole transient MAXI J1535-571 as it transitioned through its intermediate state, showing a strong low-frequency (LF) QPO which varied in frequency between 1.7 and 9.5 Hz. A currently favored model for the LF QPO is that it is associated with general relativistic precession of the innermost hot-flow or corona, and therefore probes the emission and dynamics in the strongest-gravity region of the accretion flow. Spectral-timing with NICER's soft X-ray response and CCD-quality spectral resolution provides a powerful approach to test this and other models for the QPO and study the evolution of the inner disk as the QPO frequency changes. Furthermore, due to its powerful bright-source capabilities, NICER was able to sample the QPOs in MAXI J1535-571 with photon count rates more than 40 times greater than the previous best QPO spectral-timing measurements by XMM-Newton. We use these remakable data to show how the spectral-timing properties of the QPO evolve with changing frequency and use these to test the origin of the QPO and how it is connected to changes in the innermost accretion flow.

111.23 — Using MSPs as clocks: a Report on the NICER Precision Timing Study and the SEXTANT Navigation Demonstration

Kent Wood[1]
[1] *Praxis, Inc (resident at NRL) (Arlington, Virginia, United States)*

Precision timing on MSP sources was among the original design-driving goals of the Neutron Star Interior and Composition ExploreR (NICER). Motivations include comparison with radio timing on the same sources, both to probe variable propagation effects and to evaluate feasibility of an X-ray contribution to low-frequency gravitational wave detection. The latter is presently undertaken exclusively with radio timing. Three targets (PSR B1821-24, PSR B1937+21, PSR J0218+4232) are established as the most promising for NICER study, by virtue of their being comparatively bright and having sharp pulse features. NICER has accumulated long observing time on all three. It is expected that timing precision on the order of one part in 10^{13} will be achieved on pulsars in roughly two years of mission life. Progress toward this goal is presented, using a recently-submitted publication on the first year of NICER data (Deneva et al., 2018). Scaling to larger areas indicates that an X-ray telescope with much larger collecting area than NICER could begin to achieve TOA accuracy comparable to radio measurements. A very different applied use of this precise timing is X-ray navigation of satellites in a manner similar to GPS but usable well beyond Earth, e.g., in the outer solar system where DSN methods become increasingly difficult as distance increases. The MSPs described above plus three other pulsars are being used in an engineering demonstration of this concept, called SEXTANT. The demonstration uses the NICER instrument providing data to an onboard flight software application and has performed the first real-time on-orbit demonstrations of this technique, achieving a sustained performance of better than 10 km accuracy.

112 — Stellar Compact Poster Session

112.01 — Jets from strongly-magnetized accreting pulsars

Jakob Van Den Eijnden[1]*; Nathalie Degenaar*[1]*; Tom Russell*[1]*; Rudy Wijnands*[1]*; James Miller-Jones*[3]*; Gregory Sivakoff*[2]*; Juan Hernandez Santisteban*[1]*; Alicia Rouco Escorial*[1]
[1] *University of Amsterdam (Amsterdam, Netherlands)*
[2] *University of Alberta (Edmonton, Alberta, Canada)*
[3] *Curtin University (Perth, Western Australia, Australia)*

Jets are ubiquitous in the Universe, greatly impacting their surroundings and regulating accreting flows, but remain poorly understood. One approach to understanding jet formation, from the observational perspective, is to compare objects and circumstances wherein they can and cannot be launched. Since the first searches in the late seventies, jets were never seen in accreting neutron star binaries where the neutron star's magnetic field exceeds 10^9 gauss. This observational paradigm complemented theoretical work, predicting that jets could indeed not be formed by such strongly- magnetized neutron stars. In this talk, I will present our recent discoveries of jets launched by accreting X-ray pulsars with magnetic fields of 10^{12} G, disproving this paradigm. I will first discuss detailed, long-term radio and X-ray monitoring of the jet during the super-Eddington giant outburst of Swift J0243.6+6124. Secondly, I will introduce a follow-up ATCA radio survey of accreting X-ray pulsars, revealing three more jet- launching sources. I will discuss the direct implications of these jet detections on models for jet formation by accreting neutron stars, the effect of the neutron star properties on jet power, and finally the broader link with the growing population of Ultra-Luminous X-ray pulsars.

112.02 — Monitoring the Variable Pulsar Wind Nebula of PSR J1809-1917

Noel Klingler[1]*; Oleg Kargaltsev*[2]*; George Pavlov*[1]*; Bettina Posselt*[1]
[1] *Department of Astronomy & Astrophysics, The Pennsylvania State University (Washington, District of Columbia, United States)*
[2] *The George Washington University (Washington, District of Columbia, United States)*

Pulsar wind nebulae (PWNe) are sources of nonthermal X-ray emission and prominent sites of particle acceleration. We observed the PWN created by the young and energetic PSR J1809-1917 (the candidate counterpart to the extended TeV source HESS J1809-193) with a Chandra monitoring campaign consisting of six 70-ks observation groups taken every 7 weeks. The compact X-ray nebula shows interesting and puzzling dynamics, changing in brightness and morphology over timescales of months (or less). A bright clump of X-ray emitting plasma (comparable in luminosity to the PSR) appears to be moving on the same timescales. The deep exposure combining the new and archival data (540 ks total) reveals an extended nebula with a faint collimated arcminute-scale outflow misaligned from the PWN symmetry and pulsar velocity axes. Strangely, both the compact and extended nebulae lack any morphological signatures of supersonic motion (e.g., a bow shock or tail) despite the fact that the pulsar's candidate proper motion suggests supersonic speed, and the fact that no evidence of an SNR is seen at any wavelength.

112.03 — Young black hole and neutron star systems in the nearby star-forming galaxy M33: the NuSTAR view

Jun Yang[1]; Daniel Wik[1]; Ann Hornschemeier[2]; Bret Lehmer[3]; Neven Vulic[2]; Vallia Antoniou[4]; Thomas Maccarone[7]; Benjamin Williams[5]; Frank Haberl[6]; Lacey West[3]; Andrew Ptak[2]; Paul Plucinsky[4]; Mihoko Yukita[8,2]; Andreas Zezas[4]; Dom Walton[9]; Kristen Garofali[3]

[1] *The University of Utah (Salt Lake City, Utah, United States)*

[2] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[3] *University of Arkansas (Fayetteville, Arkansas, United States)*

[4] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

[5] *University of Washington (Seattle, Washington, United States)*

[6] *Max-Planck-Institut fur extraterrestrische Physik (Garching, Germany)*

[7] *Texas Tech University (Lubbock, Texas, United States)*

[8] *The Johns Hopkins University (Baltimore, Maryland, United States)*

[9] *University of Cambridge (Cambridge, United Kingdom)*

We can learn a lot about the formation of compact objects, such as neutron stars and black holes, by studying the X-ray emission from accreting systems in nearby star-forming galaxies. The harder (E>10 keV) X-ray emission in particular allows strong discrimination among the accretion states and compact object types. A NuSTAR survey of M33 was conducted to study the distribution of X-ray binary (XRB) accretion states in an actively star-forming environment. The 6 NuSTAR observations of M33 allow us to construct diagnostic diagrams, which is used to infer XRB accretion states. We have characterized XRB accretion states for ≈32 sources. The XRBs are classified by their compact object types using NuSTAR color-intensity and color-color diagrams. We further characterize the black holes by their accretion states (soft, intermediate, and hard) and the neutron stars by their weak or strong (accreting pulsar) magnetic field. In contrast to a similar NuSTAR survey of M31 (with a low-mass XRB-dominant population), the source population is dominated by high-mass XRBs, allowing the study of a very different population with similar sensitivity. These results provide a significant improvement in our knowledge of high-mass XRB accretion states that proves valuable for theoretical XRB population synthesis studies.

112.04 — The Galactic High-Mass Gamma-ray Binary 3FGL J1405.4-6119

Robin Corbet[1,4]; Laura Chomiuk[2]; Malcolm Coe[5]; Joel Coley[3,4]; Guillaume Dubus[6]; Philip Edwards[7]; Pierrick Martin[8]; Vanessa McBride[9]; Jamie Stevens[7]; Jay Strader[2]; Lee Townsend[9]

[1] *University of Maryland, Baltimore County (Baltimore, Maryland, United States)*

[2] *Michigan State University (East Lansing, Michigan, United States)*

[3] *Howard University (Washington, District of Columbia, United States)*

[4] *NASA GSFC (Greenbelt, Maryland, United States)*

[5] *University of Southampton (Southampton, -, United Kingdom)*

[6] *Université Grenoble Alpes (Grenoble, -, France)*

[7] *CSIRO (Epping, New South Wales, Australia)*

[8] *CNRS (Toulouse, -, France)*

[9] *SAAO (Observatory, -, South Africa)*

We report the identification of 3FGL J1405.6119 as a high-mass gamma-ray binary from multi-wavelength observations. Observations with the Fermi Large Area Telescope show that gamma-ray emission from the system is modulated at a period of 13.7138 ± 0.0022 days, with the presence of two maxima per orbit with different spectral properties. X-ray observations using the *Neil Gehrels Swift Observatory* X-ray Telescope (XRT) show that X-ray emission is also modulated at this period, but with a single maximum that is closer to the secondary lower-energy gamma-ray maximum. A radio source, coincident with the X-ray source is also found from Australia Telescope Compact Array (ATCA) observations, and the radio emission is modulated on the

gamma-ray period with similar phasing to the X-ray emission. A large degree of interstellar obscuration severely hampers optical observations, but a near-infrared counterpart is found. Near-infrared spectroscopy indicates an O6 III spectral classification. This is the third gamma-ray binary to be discovered with the *Fermi* LAT from periodic modulation of the gamma-ray emission, the other two sources also having early O star, rather than Be star, counterparts. We consider at what distances we can detect such modulated gamma-ray emission with the LAT, and examine constraints on the gamma-ray binary population of the Milky Way.

112.05 — X-ray pulsars in nearby irregular galaxies

Jun Yang[1]; Silas Laycock[2]; Jeremy Drake[3]; Jaesub Hong[3]; Daniel Wik[1]; Andreas Zezas[3]

[1] *The University of Utah (Salt Lake City, Utah, United States)*

[2] *University of Massachusetts (Lowell, Massachusetts, United States)*

[3] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

The Small Magellanic Cloud (SMC), Large Magellanic Cloud (LMC) and Irregular Galaxy IC 10 are valuable laboratories to study the physical, temporal and statistical properties of the X-ray pulsar population with multi- satellite observations, in order to probe fundamental physics. The known distance of these galaxies can help us easily categorize the luminosity of the pulsars and their age difference can be helpful for studying the origin and evolution of compact objects. Therefore, a complete archive of 116 XMM-Newton PN, 151 Chandra (Advanced CCD Imaging Spectrometer) ACIS, and 952 RXTE PCA observations for the pulsars in the Small Magellanic Cloud (SMC) were collected and analyzed, along with 42 XMM-Newton and 30 Chandra observations for the Large Magellanic Cloud, spanning 1997-2014. From a sample of 67 SMC pulsars we generate a suite of products for each pulsar detection: spin period, flux, event list, high time-resolution light-curve, pulse-profile, periodogram, and X-ray spectrum. Combining all three satellites, I generated complete histories of the spin periods, pulse amplitudes, pulsed fractions and X-ray luminosities. Many of the pulsars show variations in pulse period due to the combination of orbital motion and accretion torques. Long-term spin- up/down trends are seen in 28/25 pulsars respectively, pointing to sustained transfer of mass and angular momentum to the neutron star on decadal timescales. The distributions of pulse detection and flux as functions of spin period provide interesting findings: mapping boundaries of accretion-driven X-ray luminosity, and showing that fast pulsars (P<10 s) are rarely detected, which yet are more prone to giant outbursts. In parallel we compare the observed pulse profiles to our general relativity (GR) model of X-ray emission in order to constrain the physical parameters of the pulsars. In addition, we conduct a search for pulsations in X-ray sources in the young local dwarf galaxy IC 10 to form a comparison sample for Magellanic Cloud X-ray pulsars.

112.06 — Photospheric Polarization Signatures of Long Gamma Ray Bursts

Tyler Parsotan[1]; Davide Lazzati[1]

[1] *Department of Physics, Oregon State University (Corvallis, Oregon, United States)*

An outstanding issue in the study of Gamma Ray Bursts (GRBs) is determining the radiation mechanism at play in the GRB jet that gives rise to their high energy prompt emission. The prompt emission can be explained under the framework of either the synchrotron shock model or the photospheric emission model. The SSM invokes relativistic shells with varying speeds that have been emitted by the central engine of the GRB; these collide with one another, release synchrotron radiation, and thus produce the detected non-thermal emission. The photospheric model on the other hand is based on the modification of a thermal spectrum of advected radiation that becomes non- thermal as it propagates through and eventually escapes the GRB jet.

One of the most direct ways of distinguishing between these models is from high accuracy polarization measurements of GRB prompt radiation. Thus, in order to maximize scientific output of future observatories, we need to have theoretical predictions of the polarization signatures of these radiation models for GRBs.

We use our Monte Carlo radiation transfer (MCRaT) code to simulate the prompt emission from a variety of Long GRBs hydrodynamic simulations. Under the framework of the photospheric model, we predict and characterize the spectrum, variability, and expected polarization signature for a variety of stellar progenitors and jet engine profiles.

112.07 — Long-Term Evolution in Neutron Star HMXBs: the Cases of 4U 1538-522 and 4U 1907+09

Paul Britton Hemphill[1]; Richard Rothschild[2]; Katja Pottschmidt[4,3]; Felix Fuerst[5]; Peter Kretschmar[5]; Ralf Ballhausen[6]

[1] Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (Somerville, Massachusetts, United States)
[2] University of California, San Diego (San Diego, California, United States)
[3] University of Maryland, Baltimore County (Baltimore, Maryland, United States)
[4] NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)
[5] European Space Astronomy Center (Madrid, Spain)
[6] Dr. Karl-Remeis-Sternwarte & Erlangen Center for Astroparticle Physics (Bamberg, Germany)

Neutron star X-ray binaries present useful laboratories for a number of fields of study, including stellar and binary evolution, due to their status as the endpoints of stellar life, and the behavior of matter under extreme conditions, due to the accretors' compactness. The high-mass X-ray binaries 4U 1538-522 and 4U 1907+09 are somewhat similar sources: both are slow-rotating accreting pulsars with cyclotron lines, pseudo-absorption features which characterize the magnetic field strength near the neutron star surface. Our *NuSTAR* and *Suzaku* observations of 4U 1538-522 suggest that its cyclotron line energy increased by ~5% over the late 2000s, as evidenced by a comparison to *RXTE* datasets from the early 2000s. In comparison, our preliminary results from 4U 1907+09 suggest no significant change in the magnetic field strength compared to observations from the past two decades. We additionally place the best limits yet on orbital period evolution in 4U 1538-522, which has implications for the evolutionary state of the donor star, which I will discuss.

112.08 — Spectral and temporal analysis of the first globular cluster black hole binary first black hole in a globular cluster

Tana Joseph[1]; Thomas Maccarone[2]
[1] School of Physics and Astronomy, University of Manchester (Manchester, United Kingdom)
[2] Texas Tech University (Lubbock, Texas, United States)

The first black hole binary in a globular cluster (XMMU 122939.7+075333) was discovered just over a decade ago in NGC 4472 and has consistently been found to have luminosities in excess of 2E39 erg/s. The first black hole binary in a globular cluster (XMMU 122939.7+075333) was discovered just over a decade ago in NGC 4472 and has consistently been found to have luminosities in excess of 2E39 erg/s. We use deep X-ray data to study the spectral and temporal characteristics of this source. The source spectrum once again shows evidence for emission from highly ionised oxygen, O VIII. Although the source is an ultraluminous X-ray source (ULX), it does not show the characteristic exponential roll over in its spectrum at >2keV found in other well- studied ULXs. Instead, we find that most of the flux variability is due to change in flux below 0.7 keV,seen as strong flaring where the source brightens by nearly an order of magnitude over the course of a few hours. Several other such systems have been discovered in extragalactic globular clusters in the Fornax And Virgo Clusters. Studying these globular cluster ULX systems gives us a chance to explore, compare and contrast ULXs with different compact objects, magnetic properties and donor masses, thereby leading to a greater understanding of this heterogeneous class of bright X-ray sources.

112.09 — Search for Low Mass X-ray binries in the Magellanic Clouds

Tana Joseph[1]; Vanessa McBride[2]; Lee Townsend[2]; Itumeleng Monageng[4]; Jacco van Loon[3]
[1] School of Physics and Astronomy, University of Manchester (Manchester, United Kingdom)
[2] University of Cape Town (Cape Town, South Africa)
[3] Keele University (Keele, United Kingdom)
[4] South African Astronomical Observatory (Cape Town, South Africa)

The Magellanic Clouds are our nearest galactic neighbours. The proximity of the Clouds allows us to probe their content and structure more deeply than other nearby galaxies. Their extragalactic nature also circumvents the problems of distance determination encountered within our own Galaxy. In addition, the low metallicity of the SMC means that this galaxy has similar conditions to the early Universe. The SKA precursor telescopes, MeerKAT and ASKAP, will allow us to survey the Magellanic Clouds rapidly and in great detail. One of most exciting areas of discovery this opens up is the search for low mass X-ray binaries (LMXBs). Currently, there is only one knkown LXMB in the Large magellanic CLoud and none in the Small Magellanic Cloud. LMXBs occupy a demonstrably different parameter space in terms of flux ratios to other sources, like background AGN and high mass X-ray binaries. By combining deep MeerKAT and ASKAP data with existing X-ray, optical, infrared and UV data we will be able to identify LMXBs in the Magellanic Clouds by their optical, X-ray and radio flux ratios. The radio data will also form a legacy product that will be of use in studies of galactic magnetism, supernova remnants , planetary nebulae and the interstellar medium of the Magellanic Clouds.

112.10 — Radio and X-ray Monitoring of the Recently Reactivated Radio-Loud Magnetar PSR J1622-4900

Aaron B. Pearlman[1]; Amanda Cook[2]; Ariel Amsellem[3]; Zaven Arzoumanian[4]; Teruaki Enoto[5]; Keith Gendreau[4]; Shinji Horiuchi[6]; Jonathon Kocz[1]; Thomas Kuiper[7]; Walid A. Majid[7,1]; Charles J. Naudet[7]; Thomas A. Prince[1,7]

[1] *Division of Physics, Mathematics, and Astronomy, California Institute of Technology (Pasadena, California, United States)*

[2] *Department of Physics and Mathematics, McGill University (Montréal, Quebec, Canada)*

[3] *Department of Physics, University of Chicago (Chicago, Illinois, United States)*

[4] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[5] *The Hakubi Center for Advanced Research and Department of Astronomy, Kyoto University (Kyoto, 606-8302, Japan)*

[6] *CSIRO Astronomy and Space Science, Canberra Deep Space Communications Complex (Tuggeranong, Australian Capital Territory, Australia)*

[7] *Jet Propulsion Laboratory, California Institute of Technology (Pasadena, California, United States)*

PSR J1622–4950 is the first magnetar to be discovered solely through its radio emission. After entering a radio quiescent state sometime between 2014 March and 2015 January, radio pulsations from the magnetar were redetected in 2017 April. X-ray observations of PSR J1622–4950 after its reactivation revealed significant X-ray pulsations, but the X-ray flux was found to be decaying exponentially. We present radio and X-ray monitoring observations of this magnetar following its recent radio reactivation.

We carried out radio observations over a time span of roughly 1.8 yr from 2017 May through 2019 January, typically at simultaneous observing frequencies of 2.2 and 8.3 GHz, using the NASA Deep Space Network 34 m and 70 m antennas near Canberra, Australia. Our radio measurements indicate that the magnetar exhibited significant changes in its pulse profiles, flux densities, spectral index, rate of bright single pulses, and rotational period after its radio reactivation. In addition, short-term radio emission variability was observed from PSR J1622–4950.

We also observed the magnetar between 2017 July and 2018 August using the Neutron Star Interior Composition Explorer (NICER) instrument on board the International Space Station (ISS). We selected photons in the 0.5-6 keV energy band and searched for X-ray pulsations using a rotational ephemeris derived from our radio pulsar timing measurements. We do not find strong evidence of pulsed X-ray emission, which we explain by the decay in the rate of soft X-ray thermal emission, inferred from fitting an absorbed blackbody model to the X-ray spectra. This suggests that the magnetar has reentered an X-ray quiescence state. We will discuss the results from our multiwavelength monitoring campaign and compare PSR J1622–4950's emission characteristics to other radio magnetars and high magnetic field radio pulsars.

112.11 — Magnetic field strength of a neutron-star-powered ultraluminous X-ray source

Murray Brightman[1]; Fiona Harrison[1]; Felix Fuerst[2]; Matthew Middleton[3]; Dom Walton[4]; Daniel Stern[5]; Andrew Fabian[4]; Marianne Heida[1]; Didier Barret[6]; Matteo Bachetti[1]

[1] *Caltech (Pasadena, California, United States)*

[2] *ESAC (Madrid, Spain)*

[3] *University of Southampton (Southampton, United Kingdom)*

[4] *Univeristy of Cambridge (Cambridge, United Kingdom)*

[5] *JPL (Pasadena, California, United States)*

[6] *IRAP (Toulouse, France)*

We present the significant detection of a narrow absorption line in the Chandra spectrum of an ultraluminous X-ray source (ULX) in M51. The energy of the line, at 4.5 keV, is inconsistent with atomic absorption or features related to the instrument. The identification of several ULXs as neutron star accretors leads us to believe that this absorption line is a cyclotron resonance scattering feature (CRSF), caused by the interaction of charged particles with a strong magnetic field. Assuming scattering from electrons, the magnetic field strength implied is $\sim 10^{11}$ G, however the line is far narrower than electron CRSFs previously observed. Scattering off more massive protons would imply a field strength of $\sim 10^{15}$ G, a magnetar field strength. This leads to the possibility that ULXs are powered by neutron stars with extremely strong magnetic fields.

112.12 — Inclination dependence of the non linear variability of QPOs.

Kavitha Arur[1]; Thomas Maccarone[1]

[1] *Texas Tech University (Lubbock, Texas, United States)*

Quasi-periodic oscillations (QPOs) are features that appear as peaks in the power spectrum of X-ray binaries. The bicoherence is a measure of phase coupling among triplets of frequencies, and can be used to break degeneracies between models that produce very similar power spectra. Here we present the results of a systematic study of the effects the orbital

inclination angle has on the bicoherence of observations with a QPO. We find that the high inclination (face on) and low inclination (edge on) sources exhibit different behavior as they transition from a hard intermediate to a soft intermediate state. We also present a model that suggests that this behavior can be explained by having a moderate optical depth hard X-ray emission region, so that the opacity varies significantly with inclination angle.

112.13 — The Synchrotron Emission Pattern of IntraBinary Shocks

Dinesh Kandel[1]; Roger Romani[1]; Hongjun An[2]
[1] *Department of Physics, Stanford University (Palo Alto, California, United States)*
[2] *Chungbuk National University (Cheongju, Korea (the Republic of))*

In the so-called 'spider' binaries the relativistic wind of a millisecond pulsar (MSP) interacts with a radiatively-driven wind from a low-mass companion, producing an interbinary shock (IBS). Previous work has described this shock in the momentum conserving (thin shell) limit as the collision of two isotropic winds (Canto et al 1996). Since numerical studies suggest that the pulsar wind is equatorially concentrated, we analytically extend this model to include $\sin^2$n theta pulsar winds. The result is of particular interest when the companion's wind momentum dominates ($\beta > 1$, as expected for the redback MSP, with low stellar mass companions). For black widow MSP with sub-stellar companions and beta «1, the isotropic approximation is fairly accurate.

We compute the expected synchrotron emission from such shocks, including the build-up and cooling of the particle population as it accelerates along the IBS. For reasonable parameters, this IBS flux dominates the binary emission in the X-ray band. The modeling shows subtle variation in spectrum across the IBS peak, accessible to sensitive X-ray studies. As examples we fit archival CXO/XMM data from the black widow pulsar J1959+2048 and the redback MSP J2339-0533, finding that the model reproduces well the orbital light curve profiles and energy spectra. The results indicate a very hard injected electron spectrum, indicating likely dominance by reconnection. The light curve fitting is sensitive to the geometric parameters, including the very important orbital inclination i. Coupled with optical fits of the companion star, such IBS X-ray light curve modeling can strongly constrain the binary geometry and the energetics of the MSP wind. This work was supported in part by NASA grant 80NSSC17K0024.

112.14 — Pulsar Radiative Heating in Black Widow Binaries

Paul Draghis[1]; Roger W. Romani[1]
[1] *Department of Physics, Stanford University (Stanford, California, United States)*

In the black widow binaries a millisecond pulsar (MSP) strongly heats a sub-stellar companion in a close ($P_b \sim$ few hour) orbit. Multicolor optical photometry can be used to study this heating pattern. By fitting such data to specific heating models, one may constrain the binary geometry including the important companion Roche lobe fill factor and the orbital inclination.

We report here on new multicolor photometry of four black widow binaries (PSRs J0023+0923, J0952-0607, J1124-3653 and J2241-5236) collected from a variety of telescopes, with 2m to 10m aperture. We fit this with our implementation of the ICARUS binary modeling code, measuring the binary parameters. In particular we focus on the MSP heating power. Since the observed MSP radiation is dominated by GeV gamma-rays, we compare this heating power, which is directed at the orbital/spin equator, with the observed Fermi flux, which is directed at inclination i. This ratio can be compared with predictions of pulsar beaming models, such as the 'outer gap' picture.

This work was supported in part by NASA grants 80NSSC17K0502 and 80NSSC17K0024.

112.16 — Early X-rays from the Type IIp Supernova 2017eaw

Brian Grefenstette[1]; Hannah Penn Earnshaw[1]
[1] *Space Radiation Lab, Caltech (Pasadena, California, United States)*

We present results from the early (15-30 days) X-ray monitoring of the Type IIp supernova SN2017eaw in NGC 6946 using NuSTAR and XMM-Newton. The supernova was observed at T~15 days after discovery by NuSTAR and then simultaneously by NuSTAR and XMM at T~30 days after discovery. We clearly detect the source up to ~20 keV in NuSTAR and see evidence for Fe-K emission in both XMM-Newton and NuSTAR. We discuss our results in the context of the multi-wavelength observations of SN2017eaw.

112.17 — The VERITAS Gamma Ray Burst Follow-up Program

Brian Humensky[1]
[1] *Department of Physics, Columbia University (New York, New York, United States)*

While much has been learned about the particle acceleration and emission processes at work during both the prompt and afterglow phases of gamma-ray bursts (GRBs), important questions remain, some of which can be addressed by searches for the highest-energy photons from GRBs using telescopes operating in the very high energy (VHE; E > 100 GeV) range. VERITAS, an imaging atmospheric Cherenkov telescope (IACT) array located at the Whipple Observatory in southern Arizona, has been performing follow-up observations of GRBs since mid-2006 and continues to maintain an active GRB observing program. In the context of the detection of GRB 190114C by MAGIC at energies above 300 GeV, demonstrating that an important contribution to the physics of GRBs that can be made by IACTs, we review the VERITAS GRB follow-up program. We discuss the development of analysis methods tailored to transient signals, and upper limits on the VHE emission from prominent bursts. These bursts include GRB 130427A, for which the VERITAS limits constrain radiation mechanisms in the afterglow, and GRB 150323A, for which the limits constrain properties of the environment in which the burst took place.

112.18 — The Shortest Period Eclipsing Binary

Thomas Prince[1]; Kevin Burdge[1]; Michael Coughlin[1]; James Fuller[1]; Shrinivas Kulkarni[1]; Thomas Kupfer[2]; Jan van Roestel[1]

[1] Department of Physics, Mathematics, and Astronomy, Caltech (Pasadena, California, United States)

[2] University of California at Santa Barbara (Santa Barbara, California, United States)

We describe an ultra-short period 7-minute binary identified by the Zwicky Transient Facility (ZTF). The binary exhibits both primary and secondary eclipses and is also a double-line spectroscopic binary, showing broad absorption lines in the primary and narrow emission lines in the secondary. We discuss our estimates of the parameters of the system including orbital period, masses, radii, radial velocities, and inclination. Given the period and the estimated masses, the binary is expected to be a strong gravitational wave emitter, observable by the future LISA mission. We describe ongoing timing observations undertaken to measure the expected decay of the orbit due to gravitational waves. We also discuss evolutionary scenarios for the system, in particular the attempt to explain the rather hot 50,000K temperature of the primary white dwarf.

112.19 — What can bright neutron star binaries tell us about ultra-luminous X-ray pulsars?

McKinley Brumback[1]; Ryan Hickox[1]; Matteo Bachetti[2]; Ralf Ballhausen[3]; Felix Fuerst[4]; Sean Pike[5]; Katja Pottschmidt[6,7]; John Tomsick[8]; Joern Wilms[3]

[1] Department of Physics and Astronomy, Dartmouth College (Hanover, New Hampshire, United States)

[2] INAF/Osservatorio Astronomico di Cagliari (Selargius, Italy)

[3] Dr. Karl Remeis-Sternwarte and Erlangen Centre for Astroparticle Physics (Bamberg, Germany)

[4] European Space Astronomy Centre (ESA/ESAC) (Madrid, Spain)

[5] Cahill Center for Astronomy and Astrophysics, California Institute of Technology (Pasadena, California, United States)

[6] NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)

[7] CRESST, Department of Physics and Center for Space Science and Technology, UMBC (Baltimore, Maryland, United States)

[8] Space Sciences Laboratory, University of California, Berkeley (Berkeley, California, United States)

One of the many puzzling observations of ultra-luminous X-ray (ULX) pulsars is pulsation transience. The non-detection of pulsations from typical bright pulsar X-ray binaries is usually accompanied by a decrease in flux and is therefore attributed to the propellor regime, obscuration, magnetic field variations, or irregular densities in the accreted material. Here we present the detection of a rapid pulse "turn-on" in *NuSTAR* observations of the high mass X-ray pulsar LMC X-4. The pulsations are weak or nonexistent for parts of the observation, but dramatically turn on in association with a super-Eddington accretion flare. Pulse dropout of this nature is the first of its kind detected in a bright X-ray pulsar and cannot be explained by the propeller regime. Changes in the emission geometry of the source during the flare could be responsible for observed changes in pulse phase and shape. These super-Eddington accretion effects make LMC X-4 an exciting new analogue to ULX pulsars, which exhibit similar forms of pulsation dropout and superorbital variations despite accreting at hundreds of times the neutron star Eddington limit.

112.20 — StellarICs: Stellar Inverse Compton Scattering Code for Modeling the Quiet Gamma-Ray Emission from the Sun

Elena Orlando[1]; Andrew Strong[2]

[1] Stanford University (Stanford, California, United States)

[2] MPE (Garching, Munich, Germany)

The Sun is a known quiet gamma-ray source. Its quiescent gamma-ray emission is produced by Galactic Cosmic Rays (CRs) interacting with its surface (disc component) and with its photon field (spatially extended diffuse component). This extended component, by inverse-Compton scattering of CR electrons on the solar photons of the heliosphere, extends to the whole sky and it is above the background even at large angular distances from the Sun. It was studied already with EGRET, and now with Fermi LAT with higher significance. Observations of the inverse-Compton component allow obtaining information of CRs close to the Sun and in the Heliosphere as a function of different periods of solar activity. However, precise model calculations are needed. StellarICs (Stellar Inverse-Compton scattering) is a code to compute gamma-ray emission from inverse-Compton scattering by CR electrons in the Heliosphere and in the photospheres of stars. The software is publicly available and it is under continuing development. We will present our code including up-to-date models. This code is used for analyzing the Sun in Fermi LAT data and for generating the solar template officially released with the Fermi Science Tools.

112.21 — Tidal Disruptions by Binary Black Holes in Dense Stellar Systems: Studying The Spin Magnitude and Direction of LIGO Sources

Martin Lopez[1]; Aldo Batta[3,2]; Enrico Ramirez-Ruiz[1,2]; Irvin Martinez[2]; Johan Samsing[4]

[1] *Department of Astronomy, UC Santa Cruz (Milpitas, California, United States)*

[2] *Niels Bohr Institute (Blegdamsvej, Copenhagen, Denmark)*

[3] *INAOE (San Andrés Cholula, Puebla, Mexico)*

[4] *Department of Astrophysical Sciences, Princeton University (Princeton, New Jersey, United States)*

As the era of multi-messenger astronomy is well underway there remain key mysteries as to the origin of the binary black hole (BBH) gravitational wave sources observed. The field has, in general, converged to two possible main formation channels: classical binary formation in the galactic field and dynamical assembly in dense stellar systems. The search for a promising marker of the ancestry of these BBHs has narrowed down to a few key observables, one such being the spin of the individual BH constituents and their alignment. This talk lays out the framework for how tidal disruption events (TDEs) by BBHs in dense stellar systems, such as globular clusters, can alter the expected values for the spin magnitudes and directions of LIGO BBHs. I present three unique TDE scenarios in which this process can take place and how the result of these interactions depend on each scenario.

112.22 — Multi-Component Time-Resolved Analysis of Short and Long GRB Prompt Emission from Optical to Gamma-Ray

Sylvain Guiriec[1]

[1] *Department of Physics, George Washington University / NASA Goddard Space Flight Center (Washington, District of Columbia, United States)*

The Band function traditionally used for Gamma Ray Bursts (GRB) often fails to fit their prompt emission spectra. Our new model composed of three separate components provides an excellent description of the time-resolved prompt emission of both short and long GRBs: a thermal-like and two non-thermal components. For the first time, analysis of GRBs with correlated optical and gamma-ray prompt emission shows that our new model describes very accurately the whole broadband spectrum from the optical regime to higher energy gamma rays. In addition, this model enables a new luminosity/hardness relation intrinsic to one of the non-thermal components, which is promising for establishing GRBs as standard candles. This relation will be used to (i) constrain the mechanisms powering GRB jets, (ii) estimate GRB distances from gamma-ray data only (very useful in the Era of multi-messenger astrophysics and gravitational-wave searches), (iii) probe the early Universe, and (iv) constrain the cosmological parameters. I will present this new unified model using analysis of GRBs detected with various observatories and instruments such as Fermi, CGRO/BATSE and the combination of the three instruments onboard Swift and Suzaku/WAM. I will discuss here the striking similarities of GRB spectral shapes, whose components inform on the nature of the prompt emission, as well as the possible universality of the proposed luminosity/hardness relation in the context of our new model.

112.23 — A Model for the Rate of Short Gamma-ray Bursts and Compact Object Mergers

Justin Finke[1]; Soebur Razzaque[2]; Sylain Guiriec[3]

[1] *Naval Research Laboratory (Washington, District of Columbia, United States)*

[2] *University of Johannesburg (Johannesburg, South Africa)*

[3] *George Washington University (Washington, District of Columbia, United States)*

We create a model for the rate of short gamma-ray bursts (SGRBs) from neutron star-neutron star and black hole-neutron star mergers that uses the results of GRMHD simulations. This model has a number of free parameters, which we determine from a fit to the Fermi-GBM SGRBs. We explore top-hat and Gaussian jet emission profiles, and make prediction for the number of compact object mergers expected with LIGO.

112.24 — Modeling the upper kHz QPO lags in 4U 1728-34 using X-ray reverberation

Benjamin Coughenour[1]; Edward Cackett[1]
[1] *Department of Physics & Astronomy, Wayne State University (Detroit, Michigan, United States)*

While kilohertz quasi-periodic oscillations (kHz QPOs) in neutron star low- mass X-ray binaries (NS LMXBs) have been well studied for decades since their initial discovery, the cause of these signals remains unknown, as no model has been able to accurately predict all of their spectral and timing properties. The recent detection of X-ray reverberation in several AGN and stellar-mass black hole binaries suggests the possibility that the time lags seen in kHz QPO signals is due to reverberation as well. Furthermore, since many NS LMXBs also exhibit a relativistically blurred Fe line in their spectra, likely caused by the reflection of hard X-rays off the accretion disk, one would naturally expect reverberation to occur if the source of the initial oscillations occurs in the same region as the incident flux that produces reflection. While it has been shown that the lag-energy properties of the lower kHz QPOs are unlikely to be produced by X-ray reverberation, the upper kHz QPOs behave very differently. We therefore model the upper kHz QPO lag- energy spectra using relativistic ray-tracing functions adopted from works on AGN, using archival RXTE data on 4U1728-34 where upper kHz QPOs have been detected. By modeling the time-averaged spectra in which upper kHz QPOs had been significantly detected, we create a reflected flux fraction across all energies and are able to then model the lag-energy spectra using X-ray reverberation. We explore the dependence of the modeled lag properties on several different types of reflection models in an effort to reproduce the measured lags of 4U1728-34.

112.25 — Radio Frequency Timing Analysis of the Compact Jet in the Black Hole X-ray Binary Cygnus X-1

Alexandra Tetarenko[1]; Piergiorgio Casella[2]; James Miller-Jones[3]; Gregory Sivakoff[8]; Bailey Tetarenko[4]; Thomas Maccarone[5]; Poshak Gandhi[6]; Stephen Eikenberry[7]
[1] *East Asian Observatory (Hilo, Hawaii, United States)*
[2] *INAF - Osservatorio Astronomico di Roma (Rome, Monteporzio Catone, Italy)*
[3] *ICRAR - Curtin University (Perth, Western Australia, Australia)*
[4] *University of Michigan (Ann Arbor, Michigan, United States)*
[5] *Texas Tech University (Lubbock, Texas, United States)*
[6] *University of Southampton (Southampton, Hampshire, United Kingdom)*
[7] *University of Florida (Gainesville, Florida, United States)*
[8] *University of Alberta (Edmonton, Alberta, Canada)*

Black holes drive the most powerful jets in the universe, from the kiloparsec-scale jets launched by the most massive black holes in Active Galactic Nuclei (AGN), to the smaller-scale jets launched by their stellar mass analogues in black hole X-ray binaries (BHXBs). BHXBs are typically transient in nature, evolving from periods of inactivity into a bright outbursting state lasting days to months. During an outburst, BHXBs emit across the electromagnetic spectrum, where jet emission dominates in the lower frequency bands (radio, sub-mm) and emission from the accretion flow dominates in the higher frequency bands (optical, X-ray). Time domain observations now offer a promising new way to address the key open questions in jet research (e.g., size scales, geometry, speeds, a sequence of events leading to jet launching), contrary to previous works, which have focused primarily on the spectra or morphology of these outflows. However, while time-resolved observations are a staple for BHXB studies at X-ray/optical frequencies, there are many challenges that accompany such studies at radio frequencies (e.g., distinguishing intrinsic source variations from atmospheric variations, having to routinely cycle between a target and calibrator source, limits on the number of frequency bands that can be sampled at once). In this talk, I will present new results from our simultaneous multi-band VLA radio and NuSTAR X-ray observations of the BHXB Cygnus X-1. With this data, we have developed observational techniques and computational tools designed to overcome the challenges of radio timing analysis, and ultimately connect jet variability properties to internal jet physics. The combination of these techniques and the improved capabilities of planned next-generation instruments (such as the ngVLA and ALMA-2030), will make more of these radio time domain studies possible, not just in BHXBs, but in other jet-producing sources as well.

112.26 — High Density Reflection in the X-ray binary GX 339-4

Jiachen Jiang[1]; Andrew Fabian[1]; Dom Walton[1]; Javier A. García[2]; Michael Parker[3]; James F. Steiner[4]; Jingyi

Wang[4]; John Tomsick[5]
[1] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*
[2] *California Institute of Technology (Pasadena, California, United States)*
[3] *European Space Agency (Villanueva de la Canada, Spain)*
[4] *MIT (Cambridge, Massachusetts, United States)*
[5] *University of California, Berkeley (Berkeley, California, United States)*

A weak low-temperature thermal component is commonly seen in the X-ray spectra of stellar-mass black holes (BHs) in the hard state. Another common result obtained in previous reflection-based spectral analysis is a supersolar iron abundance, while all the other elements are assumed to be solar. A disk reflection model with a higher disk density might be the solution to both problems.

We present a broad band spectral analysis of the BH binary GX 339-4 with NuSTAR and Swift using high density reflection model. The high density reflection model can explain its hard state spectra with no requirement for an additional low-temperature thermal component. For the first time, this model enables us to compare the density in the disc surface of GX 339-4 in different states. The disc density in the hard state is log(ne)≈21, 100 times higher than the density in the soft state (log(ne)≈19). A close-to-solar iron abundance is obtained by modelling the broad band spectra.

112.27 — *NuSTAR* observations of MAXI J1820+070

Douglas Buisson[1]; Andrew Fabian[1]
[1] *Institute of Astronomy, University of Cambridge (Cambridge, Cambridgeshire, United Kingdom)*

We will present results from the *NuSTAR* observations of the recent bright transient, MAXI J1820+070 (ASASSN-18ey), with a particular focus on a comparison of the evolution of the spectral and timing properties during the hard state. The spectrum changes only subtly throughout this stage of the outburst, with relativistic reflection measurements implying a change in coronal geometry but a consistently small inner disc radius. However, the characteristic timescales of the variability - low-frequency break and QPO frequency - increase strongly, by a factor of ~30. We will discuss the implications this has for the processes at work in the inner regions of X-ray binaries.

112.28 — Discovery of TeV Gamma Rays from the SS 433 Jet Interaction Regions with HAWC

Chang Dong Rho[1]
[1] *Department of Physics, University of Rochester (Rochester, New York, United States)*

Astrophysical sources of high-energy radiation such as active galactic nuclei and microquasars produce relativistic jets, where particle acceleration is expected to occur. However, until the HAWC observation of SS 433, no evidence of emission from jets or the lobes, created by jet termination and interaction, had been detected above GeV energies for any source and above X-ray energies for any Galactic source. Using 33 months of data from the High Altitude Water Cherenkov (HAWC) observatory, we present the detection of the gamma-ray emissions at >10 TeV, colocated with the two jet lobes of SS 433 without significant emission from the compact object. The observed very high- energy gamma rays imply the presence of a population of charged particles with energies extending to hundreds of TeV, and possibly even to the PeV scale. We also model and compare leptonic and hadronic scenarios to determine the more favorable driving jet particle composition. The detection of the SS 433 lobes by HAWC suggests electron acceleration in the lobes, away from the central engine, which is difficult to fully explain with current theoretical models, given the derived magnetic field strength of ~16μG.

112.29 — COSI Observations of Cyg X-1

Jarred Matthew Roberts[1]; John Tomsick[2]; Steve Boggs[1,2]; Clio Sleater[2]; Andres Zoglauer[2]; Carolyn Kierans[3,2]
[1] *University of California at San DIego, Center for Astrophysics and Space Sciences (La Jolla, California, United States)*
[2] *University of California at Berkeley, Space Sciences Laboratory (Berkeley, California, United States)*
[3] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

We report on observations of the accreting black hole Cygnus X-1 performed by the Compton Spectrometer and Imager (COSI): a balloon-borne gamma-ray (0.2-5 MeV) observatory. Using the data from a superpressure balloon flight in 2016, we investigate the variability of the intensity and spectral shape of this source in the soft gamma-ray domain. A hard tail extending to MeV energies in the spectrum has been reported by other experiments such as COMPTEL and INTEGRAL. We will discuss the spectral shape observed by COSI in this context and compare our observations with simultaneous measurements from Swift/BAT (15-50 keV) and MAXI (2-20 keV).

112.30 — ALMA studies of CK VUL (1670) imply that it is the consequence of a white dwarf-brown dwarf merger

Sumner Starrfield[1]; Charles E. Woodward[2]; S.P.S. Eyres[3]; A. Evans[4]; Albert Zijlstra[5]; Adam Avison[5]; Robert D. Gehrz[2]; Marcin Hajduk[6]; Shazrene Mohamed[7]; R. Mark Wagner[8]

[1] *Department of Earth and Space Exploration, Arizona State University (Tempe, Arizona, United States)*

[2] *University of Minnesota (Minneapolis, Minnesota, United States)*

[3] *University of South Wales (Pontypridd, UK, United Kingdom)*

[4] *Keele University (Keele, UK, United Kingdom)*

[5] *University of Manchester (Manchester, UK, United Kingdom)*

[6] *Univ of Warmia and Mazury (Olsztyn, Poland, Poland)*

[7] *SAAO (Capetown, SA, South Africa)*

[8] *Large Binocular Telescope Observatory (Tucson, Arizona, United States)*

In July 1670, observers discovered a "nova" which is now designated as Nova Vulpeculae 1670 = CK Vul. It was initially thought to be a classical nova (Shara et al. ApJ, 294, 271, 1985) but modern studies do not support that suggestion. Our (Eyres et al. 2018, MNRAS 481, 4931) new Atacama Large Millimeter/Submillimeter Array (ALMA) observations of the remnant suggest a more intresting event. These data (Band 6, in 4 spectral windows 1.875 GHz in width, centered on 224, 226, 240, and 242 GHz) trace obscuring dust in the inner regions of the associated nebulosity. The dust forms two cocoons, each extending approximately 5″ N and S of the presumed location of the central stellar remnant. Line emission from organic molecules methanamide (NH_2CHO), methanol (CH_3OH), formaldehyde (H_2CO), and CN and $C^{17}O$ is detected. CN lines trace bubbles within the dusty cocoons; methanol a N-S "S–shaped" jet; and other molecules a central cloud with a structure aligned with the innermost dust structure. The dust emission has approximate point symmetry about the radio source position (Hajduk et al. 2007, MNRAS, 378, 1298), the latter taken to be the putative location of a stellar remnant. The inner 2″ of the dust distribution is extended E-W with a sub-structure (2″ × 1″) that includes N-S extensions around the peak, suggesing a warped disk. After presenting several possibly scenarios, we find that the 1670 outburst was most likely caused by the merger of a white dwarf primary and a brown dwarf secondary. We argue the brown dwarf impact generated the unusual abundances and isotopic ratios seen in this object via nucleosynthesis (including Lithium and Aluminum). The ejected material forms the extended gas and disk observed with ALMA and that in turn drives the jets shaping the inner 6″ of the nebulosity N and S of the center of the jet and disk. We find a total dust mass of $\sim 2.04 \times 10^{-4}$ $M_\odot$ of which $\sim 1.56 \times 10^{-4}$ $M_\odot$ is in the diffuse extended emission and $\sim 4.81 \times 10^{-5}$ $M_\odot$ is in the central disk. The amount of dust, in combination with the amount of gas in the ejecta, is far too large to be the result of a classical nova outburst.

112.32 — Investigating the variability of Circinus ULX5 on multiple timescales

Sean Pike[1]; Fiona Harrison[1]; Matteo Bachetti[1]

[1] *Department of Physics, Caltech (Pasadena, California, United States)*

We present spectral and timing analysis of the variable ultra-luminous X-ray source Circinus ULX5. We characterize the flux variability of the source on a range of timescales, place constraints on long-term changes in accretion, and put limits on the presence of pulsations. We also model the spectrum of the source during the high-flux state and compare Circinus ULX5 to other accreting binaries including ULXs and high mass X-ray binaries. Understanding the spectra of ULXs and how they compare to other types of compact accretors will help to illuminate the physics of super-Eddington accretion and the nature of the inner-most regions nearest the compact object. In addition, spectral variability reveals information regarding the evolution of the accretion disk and column as well as obscuring regions further from the source.

112.33 — The Young High Mass X-ray Binary Cir X-1

Norbert Schulz[1]

[1] *Kavli Institute for Astrophysics and Space Science, MIT (Cambridge, Massachusetts, United States)*

The discovery of the X-ray remnant associated with the enigmatic X-ray binary Cir X-1 and the determination of an X-ray binary age of 4600 yr has had profound consequences towards the true nature of the binary system. Central to its extreme youth is the expectation that the neutron star in Cir X-1 has a high magnetic field. Together with its excentic orbit and simple evolutionary considerations it is literally impossible to hold up the notion that Cir X-1 is a low-mass X-ray binary, which provides specific odds since this is a system which occationally exhibits type I X-ray bursts. We observed Cir X-1 with the high energy transmission grating spectrometer (HETGS) onboard the Chandra X-ray observatory during the last decade and found the source at its lowest X-ray flux of 1.8×10^{-11} erg cm^{-2} s^{-1}. Its spectrum, a single 1.7

keV blackbody spectrum, showed a low emission radius of 0.5 km which implies a lower limit to the neutron star magnetic field between 0.4 and 2.5× 10^{11}G depending on neutron star radius. Furthermore we find X-ray line properties consistent with a photoionized wind of a B5 companion star. We discuss how this all can fit well with Cir X-1 being a very young high mass X-ray binary.

112.35 — Detection of a gamma-ray halo around Geminga with the Fermi-LAT and implications for the positron flux

Mattia Di Mauro[1]; Silvia Manconi[2]; Fiorenza Donato[2]
[1] *NASA's Goddard Space Flight Center (College Park, Maryland, United States)*
[2] *INFN (TURIN, Italy)*

An excess of cosmic positrons above 10 GeV with respect to the spallation reaction of cosmic rays (CRs) with the interstellar medium has been measured by Pamela, Fermi-LAT and with unprecedented precision by the AMS-02 experiment. Various interpretations have been invoked to interpret this excess, such as production from supernova remnants, pulsar wind nebulae (PWNe) and dark matter. A dominant contribution from dark matter is ruled out by the bounds found in gamma rays and other indirect searches. Models where supernova remnants produce secondary CRs struggle to explain the observed CR fluxes by AMS-02. Finally, severe constraints for a significant PWN contribution comes from the detection of very high-energy emission from Monogem and Geminga PWNe by Milagro and HAWC experiment. In this talk we will present a detailed study of the GeV gamma-ray halo around Geminga and Monogem, and show the constraints found for the contribution of these PWNe to the positron excess combining Milagro and HAWC data with measurements from the Fermi-LAT for the first time. We will report the detection of a significant emission from Geminga PWN derived by including the proper motion of the its pulsar. Then we will demonstrate that using gamma-ray data from the LAT is of central importance to provide a precise estimate for a PWN contribution to the cosmic positron flux. We will also present the most promising energies to detect a signal of synchrotron emission for positrons emitted by PWNe and will discuss the prospects of detecting this signature with current or future experiments.

112.36 — Caught in the act: a new transient ULX in NGC 6946

Hannah Penn Earnshaw[1]; Brian Grefenstette[1]; Felix Fuerst[2]; Fiona Harrison[1]; Marianne Heida[1]; Daniel Stern[1,3]; Dom Walton[4]
[1] *Cahill Center for Astronomy and Astrophysics, Caltech (Pasadena, California, United States)*
[2] *ESAC (Madrid, Spain)*
[3] *JPL (Pasadena, California, United States)*
[4] *Institute of Astronomy (Cambridge, United Kingdom)*

The nearby spiral galaxy NGC 6946 was recently observed twice with *NuSTAR*. The two observations were taken ten days apart, with the second observation simultaneous with an observation with *XMM-Newton*. In the second, simultaenous observation, we detect a new ultraluminous X-ray source (ULX) not detected in any previous observation of NGC 6946. Over the course of the *XMM-Newton* observation, its luminosity increases from 1.6×10^{38} to 2.8×10^{39} erg s^{-1}, undergoing flaring behaviour as it does so. A Chandra observation taken ten days after that fails to detect ULX-4, meaning that its flux decreased in that time by at least a factor of ∼25 and the entire transient event lasted a maximum of 20 days (and more likely ∼10 days). The spectrum of ULX-4 is very hard, and is equally well described as a cut-off power-law with $\Gamma = 0.7 \pm 0.1$ and $E_{cut} = 11^{+9}{}_{-4}$ keV or as a hot multicolour disc blackbody with $T = 4.3^{+0.6}{}_{-0.5}$ keV. Its hard spectrum and sudden changes in flux is similar to those exhibited by known ULX pulsars, which can be explained by the 'propeller mechanism'. However, since we only detect ULX-4 once and do not detect any pulsations which would unambiguously identify it as a neutron star, we also consider the possibility of a one-off transient event such as a micro-tidal disruption event of a low- mass star onto a stellar- or intermediate-mass black hole.

112.37 — Multiwavelength observations of Be X-ray binary PSR J2032+4127/MT91 213 through periastron

Wynn C.G. Ho[1]; Malcolm Coe[2]; Eric V. Gotthelf[3]; Jules P. Halpern[3]; Tyrel J. Johnson[4]; Matthew Kerr[5]; C.-Y. Ng[6]; Atsuo T. Okazaki[7]; Paul S. Ray[5]; Ben W. Stappers[8]; Iain A. Steele[9]
[1] *Department of Physics and Astronomy, Haverford College (Haverford, Pennsylvania, United States)*
[2] *University of Southampton (Southampton, United Kingdom)*
[3] *Columbia University (New York, New York, United States)*
[4] *George Mason University (Fairfax, Virginia, United States)*

[5] US Naval Research Laboratory (Washington, District of Columbia, United States)
[6] University of Hong Kong (Hong Kong, China)
[7] Hokkai-Gakuen University (Sapporo, Japan)
[8] University of Manchester (Manchester, United Kingdom)
[9] Liverpool John Moores University (Liverpool, United Kingdom)

Radio and gamma ray observations within the last few years showed that the binary system PSR J2032+4127/MT91 213 is composed of a 143 ms radio and gamma- ray pulsar in a very eccentric, approximately 50 year orbit around a high-mass Be star, with periastron passage on 2017 November 13. The pulsar also powers the TeV source J2032+4130. Many properties of the system are similar to the previously unique pulsar binary PSR B1259-63/LS 2883, which contains a 48 ms pulsar in a 3.4 year orbit around its high-mass companion. PSR J2032+4127 is a unique tool for testing our understanding of PSR B1259-63 and X-ray binaries but one that can only be used once every 50 years. I present selected results from our multiwavelength campaign to monitor the PSR J2032+4127/MT91 213 system through periastron passage.

This work is partially supported by NASA through a Chandra Award that is issued by the Chandra X-ray Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of NASA.

112.41 — Reflection spectroscopy of GX 339-4 in its bright-intermediate states

Navin Sridhar[1]; Javier A. García[2]; James F. Steiner[3]; Fiona Harrison[2]; Riley Connors[2]; Victoria Grinberg[4]; Thomas Dauser[5]
[1] Columbia University (New York, New York, United States)
[2] California Institute of Technology (Pasadena, California, United States)
[3] MIT Kavli Institute (Cambridge, Massachusetts, United States)
[4] University of Tübingen (Tübingen, Germany)
[5] University Erlangen-Nuremberg (Erlangen-Nuremberg, Germany)

We present the analysis of several observations of the black hole binary GX 339–4 during its bright intermediate states from two different outbursts (2002 and 2004), as observed by the Proportional Counting Arrays (PCA) on-board the Rossi X-ray Timing Explorer (*RXTE*) mission. We performed a consistent study of its reflection spectrum by employing the *relxill* family of relativistic reflection models to probe the evolutionary properties of the accretion disk including the inner disk radius (R_{in}), ionization parameter (ξ), and the temperature of the inner disk. Typical reflection signatures in the spectrum (i.e., Fe K emission, Fe K-edge, and Compton hump) are observed with very similar shape in all the analyzed spectra, qualitatively suggesting no substantial change in R_{in} across the bright intermediate states. Our analysis with the relativistic reflection models show that the disk inner-edge approaches the inner-most stable circular orbit (ISCO) early during the onset of bright hard state, and that the level of disk truncation remains close to this region ($\sim<$ 10 R_{ISCO}) throughout the transition from the hard to the soft state. This suggests that the changes observed in the temperature of inner disc during the state transition cannot solely be attributed to changes in the location of the inner disc. By comparing the aforementioned disk properties during the state transitions in two outbursts occurring at different luminosities, we found almost identical evolutionary trends, with differences only seen in the temperature and optical depth of the corona.

112.42 — X-ray and Gamma-Ray Shock Emission from Spider Binaries

Alice Harding[1]; Zorawar Wadiasingh[1,3]; Christo Venter[2]
[1] Astrophysics Science Division, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)
[2] North-West University (Potchefstroom, South Africa)
[3] USRA/NPP Fellow (Greenbelt, Maryland, United States)

Radio, optical and X-ray follow-up of unidentified Fermi sources has expanded the number of known galactic-field ”black widow” and ”redback” millisecond pulsar (MSP) binaries from four to nearly 30. Several systems observed by Chandra, XMM, Suzaku, and NuSTAR exhibit double-peaked X-ray orbital modulation. Orbital modulation has also been detected recently from two MSP binaries by Fermi. Such emission is attributed to electrons accelerated in an intrabinary shock, which cool via synchrotron and inverse Compton channels, and whose emission is Doppler-boosted along the shock in a mildly relativistic bulk flow. We present new transport and radiation calculations that may simultaneously model orbital-phase-resolved light curves and spectra from UV to TeV energies. The structure of the orbital X-ray light curves depends upon the binary inclination, shock geometry, and accelerated particle spectrum, energy losses and transport in the shock environment. In particular, the spatial variation along the shock of the underlying electron power-law index yields energy-dependent light curves, motivating future high- energy phase-resolved spectroscopic studies to probe the unknown physics of pulsar winds and relativistic shock acceleration therein. By fitting the observed X-ray and gamma-ray spectra

and light curves, we are able to constrain the particle spectrum and shock synchrotron emission spectrum downstream of the shock as well as observer geometry. Inverse-Compton emission from nearby pulsars with hot or flaring companions may be promising targets for the future Cherenkov Telescope Array (CTA) and may also be detectable by Fermi LAT for optimistic parameter choices.

112.43 — Core-collapse supernovae as cosmic ray sources

Vikram Dwarkadas[1]; Alexandre Marcowith[2]; Matthieu Renaud[2]; Vincent Tatischeff[3]; Gwenael Giacinti[4]

[1] *Department of Astronomy and Astrophysics, University of Chicago (Chicago, Illinois, United States)*

[2] *Universite Montpellier (Montpellier, France)*

[3] *Universite Paris-Sud (Orsay Cedex, France)*

[4] *Max-Planck-Institute for Nuclear Physics) (Heidelberg, Germany)*

Core-collapse supernovae produce fast shocks which pervade the dense circumstellar medium (CSM) of the stellar progenitor. Cosmic rays (CRs) accelerated at these shocks can induce the growth of electromagnetic fluctuations in the preshock medium. Using a self-similar description for the shock evolution, we calculate the growth time-scales of CR driven instabilities for a sample of nearby core-collapse radio supernovae of Type II and Ib/c. We find that extended IIb SN shocks can trigger fast intra-day instabilities, strong magnetic field amplification, and CR acceleration. In particular, the nonresonant streaming instability can contribute to about 50 per cent of the magnetic field intensity deduced from radio data. This results in the acceleration of CR particles to energies of 1–10 PeV within a few days after the shock breakout. Type IIn supernovae are also good candidates for strong magnetic field amplification and CR acceleration. However their evolution cannot generally be described in a self-similar manner, but requires detailed modelling of the blast wave dynamics coupled with particle acceleration before drawing any conclusions. Finally, we find that the trans- relativistic object SN 2009bb can accelerate CRs up to 2–3 PeV within 20 d after the outburst, even though it produces more modest magnetic field amplification.

112.44 — X-ray reflection spectroscopy of the black hole binary XTE J1550-564: how inclined is the disk?

Riley Connors[1]; Javier A. García[1]; James F. Steiner[2]; Victoria Grinberg[3]; Thomas Dauser[4]; Efrain Gatuzz[7]; Fiona Harrison[1]; John Tomsick[5]; Sera Markoff[6]; Joern Wilms[4]

[1] *Department of Astronomy & Astrophysics, California Institute of Technology (Pasadena, California, United States)*

[2] *MIT Kavli Institute (Cambridge, Massachusetts, United States)*

[3] *Institute for Astronomy und Astrophysics Tuebingen (Tuebingen, Germany)*

[4] *Dr. Karl Remeis Observatory, University of Erlangen-Nuremberg (Bamberg, Germany)*

[5] *Space Science Laboratory, University of California, Berkeley (Berkeley, California, United States)*

[6] *API, University of Amsterdam (Amsterdam, Netherlands)*

[7] *European Southern Observatory (ESO) (Munich, Germany)*

Black hole binaries (BHBs) follow distinct patterns during their outbursts, exhibiting two primary X-ray spectral states, hard and soft. Since we observe many outbursts of multiple detected BHBs (their duty cycles range from years to decades), we can trace the evolution of their accretion flows in realtime. However, despite the wealth of broadband observations, several important questions prevail, such as how fast these black holes spin, the geometry and the level of disk truncation as they evolve through accretion states. X-ray reflection spectroscopic modeling has made some strides in recent years in answering these questions. The characteristic relativistically broadened Iron K alpha line and Compton reflection hump, signatures of X-rays reflected off the optically-thick accretion disk, depend on the black hole spin, the inner radius, and the disk inclination, as well as other key properties of the accretion flow. We present detailed reflection spectroscopy of archival X-ray observations of XTE J1550-564 conducted with the *Rossi X-ray Timing Explorer (RXTE)* and the *Advanced Satellite for Cosmology and Astrophysics (ASCA)*. XTE J1550-564 is an ideal candidate to benchmark our models, since its dynamical characteristics are well-measured. Using the RELXILL model, we show that fits to the reflection spectrum of XTE J1550-564 during its hard and intermediate states lead to inclination estimates of ~30—40 deg, which are significantly lower than both the orbital inclination (~75 deg) and the inclination derived from the radio jet (within 12 deg of the orbital). This large and unexpected disparity is puzzling, and suggests we still do not fully understand the geometry of the reflector and/or the properties of the disk illumination. We discuss these contrasting inclination estimates in the framework of our ongoing efforts to fully characterize the outbursts of XTE J1550-564 using a total of 517 available archival RXTE spectra.

112.45 — Use of Supervised Machine Learning for determination of redshifts of Gamma-ray Bursts

Maria Dainotti[1,2]; Vahe' Petrosian[2]

[1] *Astronomical Observatory, Jagiellonian University (Krakow, Poland, Poland)*
[2] *Stanford (Stanford, California, United States)*

Gamma-ray bursts (GRBs) by virtue of their high luminosities are observed up to redshift z=9.4 (Cucchiara et al. 2011), far beyond the most distant quasars or galaxies. and thus have the potential to be vital cosmological probes of earlier processes in the universe, such as reionization, evolution of the star formation rate (SFR), in general, and formation of the first generation (Population III) stars. This requires a relatively large sample of GRBs with known redshifts and well defined observational selection effects. Most GRB instruments provide samples with a well defined prompt gamma-ray peak flux threshold. However, samples with redshift, requiring localization at X-rays and optical-UV follow up observations, suffer from more complex truncations, which hampers the progress to this end. The Swift satellite, the most successful instruments for measuring spectroscopic redshifts of GRBs, has provided redshifts only about one-third of GRBs it detected. The situation is even less promising for other instruments. Thus, for more than 20 years there have been attempts to increase the number of GRBs with known z via a theoretical estimate of redshift (so called pseudo-redshifts) using GRB relations, but these approaches have led to inaccurate predictions. Thus, we adopt here supervised machine learning approaches to estimate redshifts for GRBs using existing data from many instruments; Swift-(BAT,XRT), Fermi-GBM and Konus-Wind. These methods will also allow us to estimate possible non- linear relations between the redshift and other GRB characteristics. Our approach brings a novelty on this research area, because, for the first time, it adds the afterglow plateau emission characteristics. We obtained best results using the "generalized additive" model with a correlation coefficient of 0.91 between the predicted and the observed redshifts and an overall dispersion of 0.2. The addition of afterglow parameters improves the predictions by 45% compared to previous results in the published literature. We also show that using the predicted redshifts we obtain distributions and cosmological evolutions very similar to those obtained from actual measured redshifts.

112.46 — The Inner Accretion Flow in the Galactic Microquasar GRS 1758-258

Mark Reynolds[1]; Jon Miller[1]; Edward Cackett[1]
[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

GRS 1758-258 is persistent X-ray source considered to be a black hole binary on the basis of its hard X-ray emission and similarities to Cygnus X-1. The additional detection of relativistic jets is of great interest given the potential to test theoretical models of outflow physics. Previous observations of GRS 1758-258 have revealed a power-law dominated hard X-ray spectrum. Herein, we present the results of a 50 ks observation with NuSTAR. The source is clearly detected across the NuSTAR bandpass and reveals for the first time the characteristic features of relativistic reflection from the inner accretion disk at a luminosity of ~1% Eddington. We will present the results of our analysis of this observation and the constraints this places on the inner accretion flow from a persistently active microquasar.

112.48 — Characterizing the SMC X-ray pulsars with *Polestar*

Rigel Cappallo[1,2]; Silas Laycock[1,2]; Dimitris Christodoulou[1]
[1] *University of Massachusetts Lowell (Lowell, Massachusetts, United States)*
[2] *Lowell Center for Space Science and Technology (Lowell, Massachusetts, United States)*

An X-ray pulsar (XRP) is a highly-magnetized neutron star (NS) that rotates while emitting beams of X-ray radiation produced primarily in the vicinity of its magnetic poles. If these beams happen to cross our line of sight and the NS's spin and magnetic axes are not aligned, then our telescopes detect it as a periodically pulsating source. With the introduction of a new class of orbit-based observatories over the last quarter of a century the field of X-ray pulsar astronomy has seen an influx of high-resolution data. This windfall demands new models of pulsar behavior and emission geometry be created and subsequently fit to this high-quality data.

Any given XRP has a unique pulse profile which is often energy-dependent, and changes with different luminosity states. A change in luminosity coincides with a change in the system (e.g. a periodic Type-1 outburst is triggered following periastron passage, or the orientation of the decretion disk around the donor star has changed), and as such an increase in luminosity tends to produce an increase in complexity of the accompanying pulse profile. We have written a model (*Polestar*) in *Python* that mathematically represents a simplified XRP. The code has ten different, tunable geometric parameters that can be individually incorporated or suppressed. If a particular source in a low- luminosity state can be fit well with Polestar incorporating only a few parameters then an underlying geometry may be inferred. Further, if profiles from the same source in higher-luminosity states can be fit with the addition of only one or two additional parameters it will serve to further solidify current XRP theory (e.g. the emergence of fan-like emission patterns, or the vertical growth of the accretion column).

Our initial fitting campaign was directed at the ~ 100 XRPs in the Small Magellanic Cloud. Polestar will be freely available on the web to the general astrophysics community and our hope is that in the future it will be used to fit pulse profiles from any XRP in the sky.

112.49 — ULXs for a Minute: A New Giant X-ray Flare in a Nearby Galaxy

Jimmy Irwin[1]; Gregory Sivakoff[2]; Dacheng Lin[3]; W. Peter Maksym[4]; Aaron Romanowsky[5]; Ka-Wah Wong[6]

[1] *Department of Physics & Astronomy, University of Alabama (Tuscaloosa, Alabama, United States)*

[2] *University of Alberta (Edmonton, Alberta, Canada)*

[3] *University of New Hampshire (Durham, New Hampshire, United States)*

[4] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

[5] *San Jose State (San Jose, California, United States)*

[6] *Eureka Scientific (Oakland, California, United States)*

Our previous work has identified a new class of very rapid (<1 minute), high amplitude (factor of >100 increase in flux) flares in X-ray sources in nearby galaxies that flare to 10^{40} - 10^{41} erg s^{-1} that do not destroy themselves, which we have named NERFs (Non-cataclysmic Extreme and Rapid Flaring sources). NGC4636 NERF-1 and NGC5128 NERF-1 both reside within globular clusters of their host galaxies, indicating they are old objects and unlikely to be highly-magnetized neutron stars. When not flaring the sources appear to be typical X-ray binary stars. Here, we present a new NERF in the galaxy M81, which flared multiple times to ~5 x 10^{40} erg s^{-1} in archival Chandra data. Unlike the first two NERFs, M81 NERF-1 does not reside within a globular cluster of its host galaxy, but may have a relatively faint (M_V ~ -3) optical counterpart, although the poorly-known X-ray position of the source makes this uncertain. We derive X-ray light curves and spectra of this new NERF and explore possibilities as to the physical nature of NERFs.

112.50 — The First Glitch in a Central Compact Object Pulsar: 1E 1207.4-5209

Jules Paul Halpern[1]; Eric V. Gotthelf[1]

[1] *Department of Astronomy, Columbia University (New York, New York, United States)*

Since its discovery as a pulsar in 2000, the central compact object (CCO) 1E 1207.4–5209 in the supernova remnant PKS 1209–51/52 had been a stable 0.424 s rotator with an extremely small spin-down rate and weak ($B_s \approx 9\times10^{10}$ G) surface dipole magnetic field. In 2016 we observed a glitch from 1E 1207.4–5209 of at least $\delta f/f$ = (2.8±0.4)×10^{-9}, which is typical in size for the general pulsar population. However, glitch activity is closely correlated with spin-down rate *df/dt*, and pulsars with $|df/dt|$ as small as that of 1E 1207.4–5209 are never seen to glitch. Unlike in glitches of ordinary pulsars, there may have been a large increase in $|df/dt|$ as well. The thermal X-ray spectrum of PKS 1209–51/52, with its unique cyclotron absorption lines that measure the surface magnetic field strength, did not show any measurable change after the glitch, which rules out a major disruption in the surface field as a cause or result of the glitch. We will show the latest timing results and discuss the possible implications of this unexpected event.

112.51 — A Neutron-Star LMXB with the shortest orbital period so far?

Hang Gong[1]

[1] *NAOC (Beijing, China)*

We discover a previously unnoticed X-ray source with a periodic signal(probability of false alarm about 3.5e-4). Its X-Ray spectrum is an absorbed blackbody with an iron-line feature. It is located in the galactic plane and has no apparent optical counterpart(fx/fo larger than 1600). We argue it is probably a neutron-star ultra-compact X-Ray binary with the shortest orbital period so far.

112.52 — The Tail of PSR J0002+6216 and the Supernova Remnant CTB 1

Matthew Kerr[1]; Dale Frail[2]; Frank Schinzel[2]; Urvashi Rau[2]; Sanjay Bhatnagar[2]

[1] *US Naval Research Laboratory (Washington, District of Columbia, United States)*

[2] *National Radio Astronomy Observatory (Socorro, New Mexico, United States)*

Sensitive, widefield VLA observations have revealed a striking bow-shock pulsar wind nebula trailing the 115-ms gamma-ray and radio pulsar J0002+6216. The narrowly collimated, non-thermal emission stretches at least 7′ and, at a position angle of 113

deg., points to the geometric center of the supernova remnant CTB 1 about 28′ away. A timing analysis of data collected with the Fermi LAT indicate the pulsar has a proper motion of 115±33 mas/yr at a position angle of 121±13 deg. The direction and magnitude of the proper motion support the claim that PSR J0002+6216 was born from the same supernova that produced CTB 1 about 10,000 years ago. In this scenario, PSR J0002+6216 was born spinning near its current frequency, and its high velocity (>1000 km/s) suggests an unusually asymmetric supernova. We discuss the implications of this result for pulsar birth periods, asymmetric supernova explosions, and mechanisms for pulsar natal kicks, and we reflect on the powerful combination of VLA data, long Fermi observations, and cutting-edge analysis techniques.

112.53 — Multiwavelength Studies of Transitional Millisecond Pulsars: New Insights into Accretion Physics

Slavko Bogdanov[1]; Amruta Jaodand[5]; Juan Hernandez Santisteban[5]; Anne Archibald[5]; Jason W. T. Hessels[5]; Adam T. Deller[2]; James Miller-Jones[3]; Alessandro Patruno[4]

[1] *Columbia Astrophysics Laboratory, Columbia University (New York, New York, United States)*

[2] *Swinburne University of Technology (Hawthorn, Victoria, Australia)*

[3] *Curtin University (Perth, Western Australia, Australia)*

[4] *Leiden Observatory (Leiden, Netherlands)*

[5] *University of Amsterdam (Amsterdam, -, Netherlands)*

Transitional millisecond pulsars (tMSPs) are a newly recognized population of sources that undergo sporadic transformations between clearly distinguishable non-accreting radio pulsar and accreting X-ray pulsar states. In the accreting state, these systems reside in a regime where the rotation- powered outflow and the accretion inflow are energetically comparable. As such, they can offer unique insight into the physics of accretion onto magnetized objects. I will present results from our extensive multi-wavelength campaign targeting the canonical tMSP PSR J1023+0038 and the tMSP candidate 3FGL J1544.6-1125, based on observations with NICER, XMM-Newton, Chandra, HST, NuSTAR, and the VLA. I will highlight a few key findings, including the measurement of the long-term spin-down behavior of PSR J1023+0038, the extraordinary anti-correlated X-ray/radio variability, and the detection of UV pulsations with HST.

112.54 — Characterizing the Hottest Plasma in the zeta Puppis Wind with High Resolution X-ray Spectroscopy

David P. Huenemoerder[1]; Richard Ignace[2]; Nathan A. Miller[3]

[1] *NE83-559, MIT Kavli Institute (Cambridge, Massachusetts, United States)*

[2] *East Tennessee State University (Johnson City, Tennessee, United States)*

[3] *University of Wisconsin, Eau Claire (Eau Claire, Wisconsin, United States)*

X-ray emission from OB-stars reveals their winds in great detail. Line profiles are are shaped by the outflow and opacity of the wind. The presence of emission lines and the shape of the continuum are determined by the temperature distribution of the plasma. These diagnostics then constrain the underlying physical mechanisms responsible for the acceleration and heating of the winds, and ultimately the dynamics of the interstellar medium. We have obtained a very deep exposure of zeta Puppis (O4 supergiant) with the Chandra HETG Spectrometer. Here we report on analysis of the 1–7 A region which has a significant contribution from continuum emission between well separated emission lines from high-ionization species. These allow us to unambiguously study the hottest plasma present through the continuum shape and emission line strengths. We find that the emission is consistent with thermal, with the dominant component of about 10 MK, but with plasma of up to 20 MK or so required, and little to no contribution above that temperature. This relates to the maximum relative velocities of embedded wind shocks.

112.55 — Limits on Weak Equivalent Principle Violations using Fermi LAT Data

Robert Nemiroff[1]; Matipon Tangmatitham[1]

[1] *Department of Physics, Michigan Technological University (Houghton, Michigan, United States)*

Gamma-ray bursts (GRBs) may be useful probes of the gravitational equivalence principle on cosmological scales. GRBs are unique probes of the distant universe in general because they vary so rapidly, typically sub- second, and because they are so far away, typically past redshift one. The gravitational equivalence principle states, most generally, that "everything falls the same". In the case of high energy photons in the Fermi range, the weak equivalence principle (WEP) asserts that gravitation should affect them all equally so that they should move along indistinguishable paths across the universe. Previous

cosmological limits on the WEP have focused on the gravitational potential of our Milky Way galaxy, but it is shown here that WEP limits from GRB photons moving past distant clusters of galaxies would be substantially stronger. Toward this end, the relative timing of distant Fermi- LAT detected GRBs are used to place preliminary limits on WEP violations, potentially confirming that "everything falls the same" in a new regime – the distant universe, with new objects – super-GeV photons, and to a very high tolerance.

112.56 — A Catalog of Estimated Redshifts for 1366 BATSE Long-Duration GRBs from a Monte Carlo Fit to Brightness, Hardness, and Duration Data

Robert Nemiroff[1]; Amir Shahmoradi[2]

[1] *Department of Physics, Michigan Technological University (Houghton, Michigan, United States)*

[2] *Univ. of Texas at Arlington (Arlington, Texas, United States)*

Although BATSE ceased to function in 2000, its catalog of GRBs remains a large and valuable collection of uniform GRB data. Unfortunately, only 12 BATSE GRBs had measured spectroscopic redshifts. To help make BATSE data even more useful, we have computed redshift estimates for 1366 BATSE individual Long-duration Gamma-Ray Bursts (LGRBs) based on a Monte Carlo Markov Chain fit to other BATSE data and popular star formation models in a concordance universe. Specifically, the presented estimated redshift tables are based on a classification and modeling of the population distribution of BATSE LGRBs in the 5-dimensional space of redshift as well as intrinsic prompt gamma-ray emission properties: the isotropic 1024ms peak luminosity (Liso), the total isotropic emission (Eiso), the spectral peak energy (Epz), and the intrinsic duration (T90z), while taking into account the on-board detection mechanism of BATSE and sample incompleteness. The underlying assumption in our modeling approach is that LGRBs trace the cosmic Star Formation Rate and that the joint 4-dimensional distribution of the aforementioned prompt gamma-ray emission properties follows a multivariate log-normal distribution. Our modeling approach enables us to constrain the redshifts of BATSE LGRBs. We compare our predictions with the previous redshift estimates of BATSE GRBs based on the proposed phenomenological high-energy relations, including lag-luminosity, spectral peak energy, luminosity, and variability-luminosity. Our predictions are somewhat at odds with the previous estimates based on the high-energy phenomenological correlations, in particular with the estimates derived form the lag-luminosity and variability-luminosity relations. There is however, a weak but significant correlation of strength 0.26 between our predicted redshift estimates and those derived from the hardness-brightness relations. The discrepancies between the estimates can be explained by the strong influence of sample incompleteness in shaping the phenomenologically proposed high-energy correlations. The presented catalog here can be useful for demographic studies of LGRBs and other cosmological populations.

112.57 — X-ray Reverberation Mass Measurement of Cygnus X-1

Guglielmo Mastroserio[2]; Adam Ingram[3]; Michiel van der Klis[1]

[1] *Anton Pannekoek Institute for Astronomy, University of Amsterdam (Amsterdam, Netherlands)*

[2] *University of Amsterdam (Amsterdam, Netherlands)*

[3] *University of Oxford (Oxford, United Kingdom)*

Both galactic and supermassive black holes display characteristic features in their energy spectra, including an Fe Kα line and a Compton hump, that result from reprocessing of hard X-ray photons by the accretion disk. This reflected emission provides a probe of the innermost region of the accretion disk through general relativistic distortions to the line profile. However, these spectral distortions are insensitive to black hole mass, since they depend on disk geometry in units of gravitational radii. Measuring the reverberation lag resulting from the difference in path length between direct and reflected emission gives a measure of absolute photon path length differences. Therefore the length of the gravitational radius can be calibrated by a combined spectral-timing analysis, providing a means to measure black hole mass. I will present the application of our new reverberation model to RXTE data from the black hole X-ray binary Cygnus X-1. We jointly fit the time-averaged X-ray spectrum and the real and imaginary parts of the cross-spectrum as a function of energy for a range of Fourier frequencies, in order to constrain the mass of the black hole. I will show how introducing a radial ionisation profile in the disk changes our results and I will compare our reverberation mass measurement with the dynamical mass measurement of Cygnus X-1.

112.58 — A long, broadband X-ray study of Vela X-1 and its environment

Felix Fuerst[1]; Victoria Grinberg[2]; Quincy Abarr[3]; Manel Errando[3]; Fabian Kislat[4]; Henric Krawczynski[3]; Logan Press[3]; Celia Sanchez-Fernandez[1]; Jon Miller[5]

[1] ESA/ESAC (Villanueva de la Canada, Madrid, Spain)
[2] University Tuebingen (Tuebingen, BW, Germany)
[3] Washington University St. Louis (St. Louis, Missouri, United States)
[4] University of New Hampshire (Durham, New Hampshire, United States)
[5] University of Michigan (Ann Arbor, Michigan, United States)

We present preliminary results from a comprehensive observation campaign of the high-mass X-ray binary (HMXB) Vela X-1, using INTEGRAL, NuSTAR, Swift, and NICER. The campaign was organized as a follow-up to the first long-duration flight of X-Calibur, a hard X-ray polarization balloon mission. Vela X-1 is an archetypical HMXB, hosting a strongly magnetized neutron star with a spin period of around 283s. The magnetic field strongly influences the expected polarization signature, making it an ideal target for the hard X-ray polarization measurements done by X-Calibur. As a wind accreting system it shows strong flux and absorption variability, requiring simultaneous observations across the X-ray band to characterize the system completely and put the X-Calibur results into context. INTEGRAL observed the Vela X-1 system over a complete orbit of the binary system, from 2019-01-05 - 2019-01-12 (excluding eclipses), while NuSTAR observed in during the latter part of that orbit, between 2019-10-10 - 2019-01-11, together with NICER and Swift. Swift also provided daily monitoring between 2018-12-22 and 2019-01-05. As expected, the source shows strong variability, with flux variations of over a factor 10 between large flares and off-states and we measured an average luminosity of 2e36 erg/s (between 5-50keV). The INTEGRAL data show that the variability increases towards the later phases of the orbit, with the most extreme flux variations seen just before eclipse ingress. In NuSTAR the Cyclotron Resonant Scattering Feature (CRSF) around 55keV can be clearly measured. Using time- resolved spectroscopy we find significant changes in the CRSF energy, which seem to correlate a strong flare and a hardening of the continuum occurring around the middle of the observation. These data provide new insights into the location of the line-forming region as function of luminosity and time. From the soft X-ray coverage with NICER and Swift/XRT we find highly variable absorption, likely caused by wind clumps moving through our line-of-sight. We discuss these preliminary results in the context of recently developed theoretical models of the accretion column, the CRSF production, as well as the wind structure and ionization state of the system.

112.59 — Filling the Pulsar Magnetosphere with Self-Consistent Pair Discharge near the Stellar Surface

Alexander Yuran Chen[1]; Fabio Cruz[2,1]; Anatoly Spitkovsky[1]
[1] Department of Astrophysical Sciences, Princeton University (Lawrence Township, New Jersey, United States)
[2] GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico (Lisbon, Lisbon, Portugal)

Recent advances in numerical techniques and computational power have allowed us to simulate the pulsar magnetosphere from first principles using Particle-in-Cell techniques. These ab-initio simulations seem to indicate that pair creation through photon-photon collision at the light cylinder is required to sustain the pulsar engine. However for many pulsars, pair creation operates most effectively only near the stellar surface where magnetic field is high. Without efficient photon-photon pair conversion, how these "weak pulsars" fill their magnetospheres and produce radio emission is still a mystery. By pushing towards a parameter regime that was not studied in detail before, we discovered a new self-consistent solution to the pulsar magnetosphere that does not require pair production near the light cylinder. This solution exhibits quasi-periodic filling of the outer magnetosphere, together with the screening and opening of a large "gap" of unscreened parallel electric field. We will describe in detail the differences of this solution compared to the more widely known Force-Free solution, and discuss the potential observational implications.

112.60 — In search of the faintest X-ray transients: Results from the first epoch of the Swift Bulge Survey

Aarran Shaw[1]; Craig Heinke[1]; Arash Bahramian[2]; Thomas Maccarone[3]; Jamie Kennea[4]; Liliana Rivera Sandoval[3]; Erik Kuulkers[5]; Nathalie Degenaar[6]; Rudy Wijnands[6]; Jay Strader[7]; Jean in 't Zand[8]; Gregory Sivakoff[1]
[1] Department of Physics, University of Alberta (Edmonton, Alberta, Canada)
[2] Curtin University (Perth, Western Australia, Australia)
[3] Texas Tech University (Lubbock, Texas, United States)
[4] Penn State University (State College, Pennsylvania, United States)
[5] ESA (Noordwijk, Netherlands)
[6] University of Amsterdam (Amsterdam, Netherlands)
[7] Michigan State University (East Lansing, Michigan, United States)
[8] SRON (Utrecht, Netherlands)

Very Faint X-ray Transients (VFXTs) show peak X-ray luminosities in the range 10E(34-36) erg/s. The luminosities of these sources imply an extremely low time-averaged accretion rate, which remains difficult to explain in the context of binary evolution models. Of order 20 VFXTs are known, but few have multi-wavelength studies to constrain the donor star, and the total size of the population is not well known. In 2017-2018 we initiated the first phase of the Swift Bulge Survey (SBS), a wide, shallow Swift/XRT imaging survey of 16 square degrees of the Galactic Bulge, with the intention of both uncovering new and studying known VFXTs. Here I will detail the optical/NIR follow-up of sources detected in the SBS, including evidence of a symbiotic X-ray binary that exhibits X-ray bursts, and a cataclysmic variable with an unusually long orbital period of >8 days. The follow-up of sources studied in the SBS has allowed us to place constraints on their counterparts and investigate the nature of accretion in these systems.

112.61 — Hard X-ray emission from Magnetars from First Principles

Alexander Yuran Chen[1]; Andrei Beloborodov[2]
[1] *Department of Astrophysical Sciences, Princeton University (Lawrence Township, New Jersey, United States)*
[2] *Columbia University (New York, New York, United States)*

The X-ray spectrum from many magnetars exhibit a hard power law component up to a few hundred keV that in many cases dominate the total X-ray luminosity. This component is believed to originate from the magnetosphere, as a result of the dissipation of magnetic energy from twisted magnetic field lines into nonthermal particles. We present first-principle Particle-in-Cell (PIC) simulations of the magnetar magnetosphere, including the most relevant radiative processes and resolving the plasma dynamics. We show how the twisted magnetic field drives a current from the star and accelerates particles, and we can self-consistently produce a hard X-ray spectrum similar to what is observed in many magnetars. This also allows us to compare the amount of energy that radiates away as X-ray, with the amount of energy that goes back to heat the stellar surface, forming a hotspot.

112.62 — The Reanimation of Magnetar XTE J1810-197: A NuSTAR Observation of the 2018 X-ray Outburst

Eric Gotthelf[1]; Jules Paul Halpern[1]; Jason Alford[1]
[1] *Columbia Astrophysics Lab, Columbia University (New York, New York, United States)*

We present the first X-ray observation of the 2018 outburst of the magnetar XTE J1810-197, 15 years after the 2003 discovery of this, the first known transient and radio anomalous X-ray pulsar (AXP). A 13 December observation of XTE J1810-197 with the Nuclear Spectroscopic Telescope Array (NuSTAR) detected X-ray emission up to at least 30 keV with a spectrum well-modeled by blackbody plus power-law components of temperature kT = 0.72±0.02 keV and photon index Gamma = 4.15±0.20, similar to the results for the 2003 outburst. In the broad NuSTAR energy band, we find evidence of hard emission above 10 keV. Modeled as an additional power-law, its flat spectral slope is harder than that of most magnetars. In the 2-10 keV bandpass, the absorbed flux is (2.12±0.07)E-10 erg/s/cm^2, is a factor of 2 greater than the maximum flux extrapolated for the 2003 outburst. Compared to pre-outburst, the flux has increased by a factor of 360 in the 0.3-10 keV band. We also present evidence of an energy dependent phase shift of the pulsed signal, suggesting that the X-ray emission components are non-aligned at the current epoch. This may be transitory, as we find no evidence for this at later epochs during the 2003 outburst.

112.63 — High-energy Observations of Solar Flares During Solar Cycle 24th with the Fermi Large Area Telescope

Nicola Omodei[1]; Melissa Pesce-Rollins[2]; Francesco Longo[3]; Alice Allafort[1]
[1] *Stanford University (Menlo Park, California, United States)*
[2] *INFN Pisa (Pisa, Italy)*
[3] *INFN Trieste (Trieste, Italy)*

The Fermi Large Area Telescope (LAT) observations of the active Sun provide the largest sample of detected solar flares with emission greater than 30 MeV to date. These include detections of impulsive and hours-long sustained emission coincident with GOES X-ray flares as well as very fast Coronal Mass Ejections (CME). Of particular interest is the first detection of >100 MeV gamma-ray emission from three solar flares whose positions behind the limb were confirmed by the STEREO spacecrafts and the 2017 September 10 X8.2 flare associated with Ground Level Enhancement 72. Fermi-LAT detections of solar flares at high energy present a unique opportunity to explore the mechanisms of high-energy emission and particle acceleration and transport in solar

flares. We will present results from the first Fermi-LAT solar flare catalog covering Solar Cycle 24, including correlation studies with the associated Solar Energetic Particles (SEP) and CMEs.

112.64 — Dynamics of extended emission associated with the high-mass gamma-ray binary B1259-63

Oleg Kargaltsev[1]; *Jeremy Hare*[1,2]; *George Pavlov*[3]
[1] *Department of Physics, The George Washington University (Washington, District of Columbia, United States)*
[2] *University of California, Berkeley (Berkeley, California, United States)*
[3] *Pennsylvania State University (University Park, Pennsylvania, United States)*

We report the results of monitoring of the eccentric B1259-63 binary with the Chandra X-ray Observatory following the 2014 periastron passage. The observations confirm that the X-ray emitting clumps are ejected from the binary each binary cycle in the same (periastron-apastron) direction. Compared to the results of the previous monitoring campaign (between the 2010 and 2014 periastron passages), this time we find evidence suggesting that the clump is being accelerated to a projected velocity of about 0.15c on a timescale of hundreds of days. Assuming that the X-ray clump is launched near preceding periastron passage, the measured acceleration ($\sim$50 cm/s^2) sets an upper limit on the mass and kinetic energy of the clump. The observed X-ray properties of the clump are consistent with synchrotron emission from pulsar wind particles accelerated at the interface between the pulsar wind and clump. We discuss the possible connection with the gamma-ray flares observed by Fermi LAT and expectations for the next binary orbital cycle.

112.65 — The donor star of NGC 300 ULX-1/SN2010da

Marianne Heida[1]
[1] *Caltech (Pasadena, California, United States)*

SN2010da was a bright transient event in the nearby galaxy NGC 300. Discovered in 2010, it was initially classified as a supernova but quickly identified as a supernova impostor. After the 2010 outburst the system showed up as an increasingly bright X-ray source (Binder+2011), and it has been in the ULX regime for the past few years. The origin of the 2010 outburst is still unclear; the dusty progenitor has been identified as a luminous blue variable (Chornock+2010, Elias-Rosa+2010), a yellow supergiant transitioning onto a blue loop (Villar+2016) or a supergiant B[e] star (Lau+2016). X-ray observations with XMM-Newton, NuSTAR and Swift revealed that the accretor is a rapidly up-spinning neutron star (Carpano+2018, Walton+2018, Binder+2018). We have obtained deep optical through near-infrared spectra of SN2010da with X-shooter in 2018 that for the first time reveal the massive star in this system to be a red supergiant. I will discuss the implications of this discovery for the origin of the 2010 outburst and the resulting X-ray binary.

112.66 — Modeling the Energy-Dependent Pulse Profiles of the Transient Magnetar XTE J1810-197 from Outburst to Quiescence

Jason Alford[1]; *Jules Paul Halpern*[1]; *Eric Gotthelf*[1]
[1] *Columbia University (New York, New York, United States)*

We model the pulsed X-ray emission from the transient magnetar XTE J1810-197 as it evolved from its 2003 outburst toward its eventual quiescent state, using the 'three-to-two blackbody' model described in Alford and Halpern 2016. Pulse profiles are computed using a general relativistic model that includes the important effects of light bending and gravitational redshift. The size and temperature of the heated regions are precisely measured at each epoch, and strong constraints are placed on the viewing geometry. We find that the presence of the 'whole surface' component in our spectral model contributes to the suppressed pulsed fraction observed at lower energies, an effect that was previously entirely attributed to anisotropic emission at the neutron star surface. We also present evidence, based on independent distance measurements, that XTE J1810-197 is more massive than the canonical 1.4 solar mass neutron star.

112.67 — Application of High-Density Reflection Models to Black Hole Spectra

John Tomsick[1]; *Javier A. García*[2]; *Andrew Fabian*[3]; *Timothy Kallman*[4]; *Michael Parker*[5]; *Jeremy Hare*[1]; *Jiachen Jiang*[3]; *Yanjun Xu*[2]; *Fiona Harrison*[2]
[1] *Space Sciences Laboratory, UC Berkeley (Berkeley, California, United States)*
[2] *Caltech (Pasadena, California, United States)*
[3] *Cambridge (Cambridge, United Kingdom)*
[4] *NASA/GSFC (Greenbelt, Maryland, United States)*
[5] *ESAC (Madrid, Spain)*

The X-ray spectra of accreting black holes (BHs) show a reflection component that is formed when hard X-rays irradiate the disk. This component includes a fluorescent iron emission line, an iron absorption edge, and an excess at tens of keV. Relativistic velocities of the disk material and a redshift from the BH's gravitational field distort the reflection component. This distortion allows for a determination of the inner radius of the optically thick disk, which often provides a constraint on the BH spin for stellar mass BHs and Active Galactic Nuclei (AGN). The vast majority of previous reflection studies have assumed a disk density that is appropriate for AGN, but disks around stellar mass BHs are estimated to be much higher in density. We are developing high-density models and have applied them to the stellar mass BHs Cyg X-1 and GX 339-4. We are now in the process of starting an Astrophysics Data Analysis project to apply the models toNuSTAR, XMM, Suzaku, and Swift spectra of more BH systems in order to refine the models and to determine if using the higher densities leads to changes in other quantities measured using the reflection technique.

112.68 — Exploring X-ray sources within the unidentified Fermi LAT sources

Oleg Kargaltsev[1]*; Jeremy Hare*[2,1]*; Igor Volkov*[1]
[1] *Department of Physics, The George Washington University (Washington, District of Columbia, United States)*
[2] *University of California, Berkeley (Berkeley, California, United States)*

We are performing a systematic census of X-ray sources in the fields of unidentified Fermi LAT sources observed with Chandra X-ray Observatory (CXO). For unIDed LAT sources we have explored and characterized the point-like and extended X-ray sources found within the GeV positional uncertainty ellipses. We use manual and automated classification methods, which include additional multiwavelength datasets, to identify the nature of the sources. We provide a summary of the current results and report some interesting findings such as a bright PSR/PWN candidate in the field of 3FGL J1016.5–6034.

112.69 — Automated search for extended sources in archival Chandra X-ray Observatory data

Oleg Kargaltsev[1]*; Igor Volkov*[1]
[1] *Department of Physics, The George Washington University (Washington, District of Columbia, United States)*

An automated search for extended sources is being carried out in the archival imaging observations performed with the Chandra X-ray Observatory Advanced CCD Imaging Spectrometer (ACIS). We describe the automated approach, the source detection and characterization, and the results of performance testing and validation. We also report our preliminary findings from the searches preformed for the ACIS observations of the Galactic plane fields.

112.70 — Decomposing the *Suzaku* spectrum of Ultra-Luminous X-ray source NGC 1313 X-1

Shogo Kobayashi[1]
[1] *Department of Physics, Tokyo University of Science (Shinjuku-ku, Tokyo, Japan)*

Ultra-Luminous X-ray sources (ULXs) are unusually luminous point sources located at off-nucleus regions of other galaxies. Their central objects are expected to be either intermediate mass black holes (BHs) accreting matters at sub-Eddington rates (e.g., Makishima et al. 2000) or stellar mass BHs/neutron stars with accretion rates above the Eddington (e.g., Mineshige 2007). Their X-ray spectra vary significantly as a function of luminosity, and some are known to exhibit a state called Multi-Color-Disk-like (MCD) state at their highest luminosities. Due to its convex continuum, the MCD state spectrum is often explained with a single accretion disk model, which is an accretion flow solution at near or above the Eddington (Watarai et al. 2000). However, some studies showed that an alternative multi-component modeling is favorable to explain variabilities of several MCD state spectra (e.g., Middleton et al. 2011). Since the state lacks characteristic spectral features, these modelings degenerate, and additional pieces of model-restricting information are required. In the present work, an X-ray data set of a representative ULX, NGC 1313 X-1, is analyzed. The observation was done with *Suzaku* on 2014 May 27th with an exposure of 100 ks. The source resided in the MCD state throughout the observation, yielding average X-ray luminosity of $2{\times}10^{40}$ erg sec^{-1}. Furthermore, the source showed strong variability in luminosity, and the change was prominent mainly in $\geqq$ 1 keV. This suggests that a stable component is present in 0.5—1 keV band. To extract the spectrum of this possible extra component, a spectral-decomposing method introduced in an active galactic nucleus study (Noda et al. 2011) was employed in the ULX study for the first time. A spectrum of the "buried" extra component was successfully extracted from the data, and it was well fitted with a standard accretion disk model with inner-disk temperature and inner- disk radius of $\sim$ 0.3 keV and $\sim$ 1600 km, respectively. The results shows that the MCD state spectrum of NGC 1313 X-1 is actually composed of several components, and the central object is estimated to be as massive as $\sim$80 $M_{\odot}$. The mass estimation is consistent with a previous work (Bachetti et al. 2012).

112.71 — NGC300 ULX1: spin evolution and super-Eddington accretion

Georgios Vasilopoulos[1]; Filippos Koliopanos[2]; Frank Haberl[3]; Stefania Carpano[3]; Paul S. Ray[4]; Chandreeye Maitra[3]; Charles Bailyn[1]

[1] *Yale Univestity (New Haven, Connecticut, United States)*

[2] *CNRS/IRAP (Toulouse, France)*

[3] *MPE (Munich, Germany)*

[4] *U.S. NRL (Washington, District of Columbia, United States)*

Ultra luminous X-ray Pulsars (ULXPs) are bright binary systems that host a Neutron Star (NS) and emit radiation in excess of the Eddington Limit expected for isotropic accretion. We have studies the spectral and spin properties of the ULXP NGC300 ULX1 through archival data, and have shown that its spin evolution from ~126 s down to 16 s is consistent with almost constant accretion between 2014 and 2018. Moreover, based on the 2018 Swift/XRT and NICER monitoring campaigns of the system we have concluded that even during an 100 d period where the observed flux drops by a factor of 20, the spin-up rate and thus the mass accretion rate remained almost constant. This can be explained only by invoking extreme X-ray absorption or obscuration due to extreme outflows from the accretion disk, or disk precession. Finally, an intriguing consequence is that assuming constant spin-up rate a NS spin reversal should have occurred around 2012.

112.72 — Mass Transfer Within Hierarchical Triples: New Models for Type Ia Supernovae and Gravitational Mergers

Rosanne Di Stefano[1]

[1] *CfA (Cambridge, Massachusetts, United States)*

Multiple stars are the progenitors of events as diverse as Type Ia supernovae and gravitational-wave-induced mergers. Mysteries abound about which systems actually produce the events and yield rates consistent with observations. We report on a recently explored mechanism: mass transfer from the third star in a hierarchical triple. We show that triples of known types can enhance the rates of black-hole/black-hole mergers. Our primary focus, however, is on new models of Type Ia supernovae in which mass transfer from a third star helps to merge some double-degenerate binaries. In other systems it can instead help a white dwarf not able to gain enough mass from its binary companion to nevertheless achieve the critical mass needed for explosion. Our models of mass transfer within triples provide second chances for a interacting binaries to produce Type Ia supernovae and other highly energetic events. If the evolutionary pathways we explore are common, a subset of X-ray binaries may actually consist of accreting binaries within hierarchical triples.

112.73 — Spatial distribution of black hole binaries within $\sim$ 1 pc of the Galactic Center revealed by Chandra and NuSTAR X-ray observations

Charles Hailey[1]; Kaya Mori[1]; Shifra Mandel[1]; Yvette Schutt[1]; Anna Coerver[2]

[1] *Department of Physics, Columbia University (New York, New York, United States)*

[2] *Barnard College (New York, New York, United States)*

The recent discovery of a dozen quiescent X-ray binaries in the vicinity of Sgr A* suggests a density cusp of hundreds of black hole (BH) LMXBs (Hailey et al. 2018), indicating over 10,000 isolated stellar-mass BHs, as predicted by the theoretical models of compact objects interacting dynamically with the supermassive BH. We report three on-going investigations identifying BH binaries and determining their spatial distribution in the central pc region. (1) We are analyzing additional Chandra ACIS-S data of the GC point sources and identify them by both spectral and timing properties. For example, further Chandra ACIS analysis detected another quiescent BH-LMXB candidate, which is highly variable with non-thermal X-ray spectra, at r~1 pc. (2) We present NuSTAR observations of two new X-ray transients detected by the Neil Gehrels Swift Observatory in the central parsec region in 2016. Their broadband (3-79 keV) spectral and timing characteristics are consistent with those of BH binaries, confirming an overabundance of X-ray transients including another BH transient detected with radio jet (Muno et al. 2005). (3) We also present our systematic study of all the previously detected X-ray transients within ~50 pc in the GC, particularly, on their outburst history. Frequent monitoring of the GC by Swift and other X-ray telescopes over the past two decades surveyed the outburst history of all GC transients, including very faint X-ray transients with peak luminosity below 10^{36} erg/s, more thoroughly than elsewhere in our Galaxy (e.g., globular clusters). For example, all six NS- LMXBs identified within the central $\sim$ 50 pc region have had recurrent X-ray outbursts with a frequency of ~5 years or less, whereas all BH-LMXBs outbursted only once or never in the past two decades. A combination of the 13 quiescent

BH-LMXBs discovered by Chandra and the three BH transients, allows us to investigate their spatial distribution in the central 1 pc region. Our results have strong implications for binary formations in galactic nuclei and test the predictions from recent theoretical models.

112.74 — NuSTAR and VERITAS observations of TeV gamma-ray binary HESS J0632+057: probing the intra-binary shocks formed by the collision of pulsar and stellar winds

Charles Hailey[1]; Kaya Mori[1]; Shifra Mandel[1]; Raul Prado[2]

[1] *Department of Physics, Columbia University (New York, New York, United States)*

[2] *DESY (Zeuthen, Germany)*

HESS J0632+057 belongs to a rare subclass of six binaries detected above E∼100 GeV. It harbors a Be companion star and likely a neutron star orbiting around each other at ∼315 day period. In such a unique binary system, high energy emission originates from particle acceleration in the shocks formed by the collision of pulsar and stellar winds. X-ray and gamma-ray emission, resulting from synchrotron radiation and inverse Compton scattering of seed photons emitted from the high-mass companion, show a strong dependence on orbital phase with a sharp "primary" peak followed by a dip and a broader "secondary" peak in the Swift and VERITAS light curves. In November and December 2017, NuSTAR and VERITAS conducted two simultaneous observations of HESS J0632+057 near the primary X-ray peak. These observations allowed us to characterize the broad-band X-ray and TeV spectra well. NuSTAR 3-79 keV spectroscopy, where the low energy absorption is negligible, unambiguously detected a variation of the intrinsic non-thermal X-ray spectra between the two observations. As a result of fitting our leptonic wind-collision model to the multi-wavelength SED data, we were able to constrain the magnetic field strength and electron energy distribution in the shock region. In addition, we present our model predictions for periastron as well as the interaction between the pulsar and dense circumstellar disk, which can be tested by future X-ray and gamma-ray observations.

112.75 — 2FHL J0826.1-4500: Discovery of a possible shock-cloud interaction on the Western edge of the Vela SNR

Jordan Eagle[1]; Stefano Marchesi[1]; Daniel Castro[2]; Marco Ajello[1]; Luigi Tibaldo[3]; Laura Duvidovich[4]

[1] *Department of Physics & Astronomy, Clemson University (Clemson, South Carolina, United States)*

[2] *Harvard Smithsonian Center of Astrophysics (Cambridge, Massachusetts, United States)*

[3] *IRAP/Observatoire (Midi-Pyrénées, Midi-Pyrénées, France)*

[4] *CONICET – Universidad de Buenos Aires, Instituto de Astronomía y Física del Espacio (IAFE) (Buenos Aires, Buenos Aires, Argentina)*

We report on the investigation of a very high energy (VHE), Galactic gamma- ray source recently discovered at E>50GeV using the Large Area Telescope (LAT) on board Fermi. This object, 2FHL J0826.1-4500, displays one of the hardest E>50GeV spectra (photon index ∼1.6) in the 2FHL catalog, and a follow-up observation with XMM-Newton has uncovered diffuse, soft thermal emission at the position of the gamma-ray source. A detailed analysis of the available multi-wavelength data shows that this source is located on the Western edge of the Vela supernova remnant (SNR): the observations and the spectral energy distribution modeling support a scenario where this gamma-ray source is the byproduct of the interaction between the SNR shock and a neutral Hydrogen cloud. If confirmed, this shock-cloud interaction would make 2FHL J0826.1-4500 a promising candidate for efficient particle acceleration.

112.76 — MAXI J1621-501: The First Source Identified by the Swift XRT Deep Galactic Plane Survey Collaboration

Nicholas Gorgone[1]; Chryssa Kouveliotou[1]

[1] *Department of Physics, George Washington University (Washington, District of Columbia, United States)*

The transient source MAXI J1621-501 was discovered in October 2017 with the Japanese instrument MAXI on the International Space Station. The source is located within one of the fields of our Swift XRT Deep Galactic Plane Survey, which we had observed prior to the source activation, allowing us to derive a flux upper limit. We subsequently joined forces with the MAXI-ISS team and followed the source evolution for 520 days. During this interval, we triggered our ToO observations with Chandra and we also observed the source with ATCA, Gemini, NuSTAR, NICER and INTEGRAL. These combined data sets led to the identification of the source nature as a Type I X-ray burster in a Low-Mass X-ray Binary. We will discuss our results of the spectral and timing analysis of the source persistent emission and of the numerous Type-I bursts detected with multiple instruments. We will also discuss the long-term light curve of the source, which exhibits additional bursting episodes during the decay phase of the overall outburst.

112.77 — Electron Spectrum of the Dragonfly Nebula at the Highest Energies with HAWC

Chad Brisbois[1]; Vikas Joshi[2]
[1] *Department of Physics, Michigan Technological University (Houghton, Michigan, United States)*
[2] *MPIK (Heidelberg, Baden-Württemberg, Germany)*

Seen from radio to GeV, PSR J2021+3651 is associated with the Dragonfly nebula, an X-ray PWN in the Cygnus region. In X-rays, the nebula is a few arcseconds across, whereas it appears much more extended at TeV energies. The TeV gamma-ray source 2HWC J2019+367 was originally discovered in 2007 by the Milagro Observatory and has been associated with this pulsar. Recent work with HAWC data has shown hints of energy dependent morphology for the source at TeV energies, supporting the interpretation of this emission being attributed to Inverse Compton scattering of electrons and positrons with interstellar radiation fields and CMB photons. The hard spectrum and softening above 30 TeV of the source is consistent with Klein-Nishina suppression of the electron- photon cross-section at high energies. We will present our most recent analysis & modeling of 2HWC J2019+367 up to the highest energies using the latest data from the HAWC Observatory.

112.78 — Chandra-HETGS Characterization of an Outflowing Wind in the accreting millisecond pulsar IGR J17591-2342

Michael Allen Nowak[1]; Adamantia Paizis[2]; Gaurava K. Jaisawal[3]; Jérôme Chenevez[3]; Sylvain Chaty[4]; Francis Fortin[4]; Jerome Rodriguez[4]; Joern Wilms[5]
[1] *Department of Physics, Washington University, St. Louis (St. Louis, Missouri, United States)*
[2] *Istituto Nazionale di Astrofisica, INAF-IASF (Milano, Italy)*
[3] *National Space Institute, Technical University of Denmark (Lyngby, Denmark)*
[4] *AIM, CEA-Saclay (Paris, France)*
[5] *Dr. Karl Remeis-Observatory & ECAP (Bamberg, Germany)*

IGR J17591-2342 is an accreting millisecond X-ray pulsar discovered in 2018 August in scans of the Galactic bulge and center by the INTEGRAL X-ray and gamma-ray observatory. It exhibited an unusual outburst profile with multiple peaks in the X-ray, as observed by a variety of X-ray satellites over the course of three months. Here we present observations of this source performed in the X-ray/gamma-ray and near infrared domains. We focus on a simultaneous observation performed with the Chandra-High Energy Transmission Gratings Spectrometer (HETGS) and NICER. With the former instrument, we obtain high resolution spectra of the Si-edge region, which provide clues as to the source's distance and reveal evidence of an outflow with a velocity of 2800 km s^{-1}. We show that there is good agreement between the NICER and Chandra-HETGS continua, provided that one properly accounts for the differing manners in which these two instruments view the dust scattering halo in the foreground of this source. Unusually, we find a possible set of Ca lines in the HETGS spectra. We hypothesize that IGR J17591-2342 is a neutron star low mass X-ray binary at a distance of the Galactic bulge or beyond that may have formed from the collapse of a white dwarf system in a rare, calcium rich Type Ib supernova explosion.

112.79 — The X-ray continuum of accreting pulsars observed with Suzaku

Katja Pottschmidt[1,2]; Diana M. Marcu[1,2]; Mike Wolff[3]; Amy Gottlieb[4]; Paul Britton Hemphill[5]; Ralf Ballhausen[6]; Sebastian Falkner[6]; Fritz-Walter Schwarm[6]; Felix Fuerst[7]; Peter Becker[8]; Kent Wood[9]; Joern Wilms[6]
[1] *University of Maryland Baltimore County (Baltimore, Maryland, United States)*
[2] *NASA-GSFC (Greenbelt, Maryland, United States)*
[3] *NRL (Washington, District of Columbia, United States)*
[4] *University of Florida (Gainesville, Florida, United States)*
[5] *MIT (Cambridge, Massachusetts, United States)*
[6] *FAU (Erlangen-Nuremberg, Germany)*
[7] *ESA-ESAC (Madrid, Spain)*
[8] *GMU (Fairfax, Virginia, United States)*
[9] *Praxis Inc. (Alexandria, Virginia, United States)*

The hard X-ray continuum emission observed from accreting pulsars like LMC X-4 or Cen X-3 is thought to be produced in accretion columns, i.e., by the accreted plasma falling towards the magnetic poles of the neutron star at relativistic speeds. We are entering an era where properties of the neutron star and the plasma flow can be studied by applying new physical models to describe the observed X-ray continuum emission.

We present an analysis of Suzaku data of a sample of accreting pulsars. We first model the spectra using commonly applied empirical continuum models based on power-law shapes with a roll-over at high energies. This allows us to constrain the parameter space for additional components of the spectra like absorption, iron lines of different ionization stages, cyclotron lines (and thus the mag-

netic field strengths), and the often required broad "10 keV bumps". We compare the results to a previously published sample study based on RXTE data by Coburn et al. (2002). Among other things the results confirm the presence of a correlation between the energy and width of the cyclotron lines, suggesting that the width is dominated by thermal broadening.

We then apply the accretion column model published by Becker and Wolff (2007) that describes the continuum as the sum of Comptonized contributions from three different seed photon sources, bremsstrahlung, blackbody radiation, and cyclotron emission, We find that the observed continuum emission is well described by this model, with the exception of in the case of the lower B-field source 4U 0115+63. We determine parameters like the accretion column radius and the plasma temperature. Providing a consistency check for the underlying physical picture we find a clear correlation between the accretion column temperature of the physical fits and spectral curvature, i.e., the folding energy of the empirical fits.

112.80 — Searches for Galactic Center Pulsars at High Radio Frequencies

Walid Majid[1]; Thomas Prince[2]; Aaron B. Pearlman[2]; Jonathon Kocz[2]; Shinji Horiuchi[3]
[1] *JPL, Caltech (Pasadena, California, United States)*
[2] *Caltech (Pasadena, California, United States)*
[3] *CSIRO (Canberra, Australian Capital Territory, Australia)*

Over the past few years, a number of groups using data from the Fermi LAT instrument have identified excess gamma-ray flux toward the inner regions of the Galactic Center (GC). One leading interpretation of the observed excess is the emission of gamma-rays from a large number of millisecond pulsars (MSPs), with a distribution that is strongly peaked toward the GC. This hypothesis can be put to test by carrying out a sensitive search for MSPs from this region of the Galaxy. To date a number of pulsar searches in the direction of the GC have been carried, so far without a detection of the expected MSP population, most likely due to extreme pulse broadening, which adversely affects the sensitivity of radio searches. We have recently developed a sensitive pulsar search capability at the Deep Space Network's 70-m dish in Canberra, Australia. This instrument, operating at high radio frequencies, is expected to significantly reduce the effects of pulse broadening, offering improved sensitivity for detection of steep spectrum radio pulsars. We will discuss new results from a study of radio pulses from the Galactic Center magnetar, and implications for detection of new pulsars in this region of the Galaxy.

112.81 — Polarization Signatures of the Resonant Compton Upscattering Model for Magnetars

Zorawar Wadiasingh[1]; Matthew Baring[2]; Alice Harding[3]; Kun Hu[2]; Peter L. Gonthier[4]
[1] *Gravitational Astrophysics Laboratory, Code 663, NASA/GSFC USRA (Greenbelt, Maryland, United States)*
[2] *Rice University (Houston, Texas, United States)*
[3] *NASA/GSFC (Greenbelt, Maryland, United States)*
[4] *Hope College (Holland, Michigan, United States)*

Magnetars are young neutron stars with high surface magnetic fields, exceeding 10^{13} Gauss. Pulsed nonthermal quiescent X-ray emission extending between 10 keV to >150 keV has been observed in about 10 magnetars by RXTE, INTEGRAL, Suzaku, NuSTAR and Fermi-GBM. For inner magnetospheric models of such hard X-ray signals, resonant Compton upscattering of soft thermal photons from the neutron star surface is the most efficient process for generating the continuum radiation in high magnetic fields. Such upscattering emission is anticipated to exhibit strong polarization above around 30 keV that is pulse phase dependent. These signatures define science agendas for future hard X-ray polarimeters and Compton telescopes. In this paper we present detailed model predictions of emission spectra and polarization signals, addressing prospects for measuring the spectral cutoffs with a future Compton telescope such as AMEGO. Phase-resolved, spectropolarimetric observations will be critical in assessing the zones of activation, as well as constraining the viewing geometry and the angle between the magnetic and spin axes of magnetars. Polarization measurements may also probe fundamental strong-field QED processes operating in the magnetar magnetospheres, potentially distinguishing between spectral cutoffs due to magnetic pair production or photon splitting. Thus, polarization probes of magnetar X-ray emission can provide insights into Nature that are currently beyond the reach of current terrestrial experiments.

112.82 — Constraints on Emission and System Geometry from Non-thermal X-ray Orbital Modulation in Redback-type Millisecond Pulsar Binaries

Zorawar Wadiasingh[1]; Sunil Chandra[2]; George Younes[3]; Alice Harding[4]; Christo Venter[2]
[1] *Gravitational Astrophysics Laboratory, Code 663, NASA/GSFC USRA (Greenbelt, Maryland, United States)*

[2] *Centre for Space Research, North-West University (Potchefstroom, North-West, South Africa)*
[3] *George Washington University (District of Columbia, District of Columbia, United States)*
[4] *NASA/GSFC (Greenbelt, Maryland, United States)*

Black widows and redbacks, a subset of millisecond pulsar binaries, are known to exhibit non-thermal orbital modulation at X-ray and gamma-ray energies. All sensible models of such orbital modulation ought to couple to the binary inclination i. We construct a physically-motivated and simplified two-parameter model function for the orbitally-modulated light curves. By reanalyzing and fitting all publicly available X-ray data, we establish that the model adequately describes the gross features of the high-energy orbital modulation. The parameter in the model associated with binary inclination is found to correlate independently with binary inclination constrained via mass functions and optical light curve models of the companion. This suggests some universality in the emission geometry of the putative intrabinary shock, and enables independent constraints on the binary inclination solely by X-ray observations of such orbital modulation. This simple function may be readily adapted in analyses of future X-ray and gamma-ray observations of orbital modulation. We also briefly describe stability of the shock to dynamical perturbations for redbacks and how observations of correlated X-ray-optical variability may test self-regulatory stabilizing mechanisms.

112.83 — Swift-XRT Follow-up of O2 GW Triggers: A Study of the X-ray Transient Population

Noel Klingler[1]; Phil Evans[2]; Jamie Kennea[1]; Aaron Tohuvavohu[1]
[1] *Department of Astronomy & Astrophysics, The Pennsylvania State University (Washington, District of Columbia, United States)*
[2] *University of Leicester (Leicester, United Kingdom)*

Detecting and studying the electromagnetic counterparts to gravitational wave (GW) events is crucial toward advancing our understanding of the merging of compact objects. This can prove challenging as the current array of GW observatories can only localize merger events to regions encompassing, at best, many tens of square degrees. Consequently, optical followup searches result in hundreds of transients and potential counterparts. Conversely, the X-ray sky is less active and X-rays can therefore serve a unique role in counterpart identification. However, the properties of the soft X-ray transient population are not as well-known and the rates uncertain. During the LIGO/Virgo Collaboration's 2nd observation run (O2), Swift followed up on 8 GW triggers, covering hundreds of square degrees with over 1 Megasecond of observing time. We present the results of Swift's O2 follow-up campaign of binary black hole mergers and the properties of the population of detected spurious X-ray sources and transients. We also discuss the implications of these results for X-ray follow-up searches in future GW observing runs.

112.84 — Measuring the mass exchange in the pulsating ultraluminous x-ray source M82 X-2

Matteo Bachetti[1]
[1] *INAF-Osservatorio Astronomico di Cagliari (Selargius, CA, Italy)*

M82 X-2 is the first discovered pulsating ultraluminous x-ray source (PULX), and the one with the shortest orbital period. The luminosity of this object seems to imply a high mass accretion rate, probably due to Roche Lobe overflow. If so, this mass exchange is bound to produce visible changes of the orbital period in a relatively short time. I present a new, precise orbital solution for this system, and discuss the implications on the total mass exchange of the system.

112.85 — The Pulsar Sequence

Constantinos Kalapotharakos[1,2]; Alice Harding[2]; Demos Kazanas[2]; Zorawar Wadiasingh[2]
[1] *University of Maryland, College Park (College Park, Maryland, United States)*
[2] *NASA, Goddard Space Flight Center (Greenbelt, Maryland, United States)*

A decade of Fermi-LAT operations has provided a wealth of observational data that shifted the study of gamma-ray pulsars from discovery to astronomy. Moreover, recent observations from ground-based imaging atmospheric Cherenkov telescopes has revealed multi-TeV pulsed emission. The consensus from the recent theoretical modeling is that the pulsar high-energy emission is produced in the equatorial current sheet outside the light cylinder. I will discuss how the observational data along with theoretical considerations constrain the various emission processes (curvature, synchrotron, inverse Compton). I will show that the entire Fermi pulsar population (young and millisecond pulsars) lies on a Fundamental Plane that connects the total gamma-ray luminosity, the cut-off energy, the spin-down power, and the stellar surface magnetic field, which is consistent with curvature radiation emission. Nonetheless, synchrotron radiation can reproduce the lower energy (up to infrared) segment of the pulsar spectrum, while its photons can serve as the seeds that produce emission up to multi-TeV radiation in inverse Compton interactions with the high-energy curvature emitting electrons. Finally, I will present our innovative kinetic PIC models of global pulsar magnetospheres with magnetic-field-line dependent particle injection. I will show not only how our simulations validate the above description but also how the particle population, which is injected near the separatrix that separates the open from the closed field lines, regulates the Fermi-LAT gammaray emission. Our simulations, more accurately than ever before, reproduce the observed Fermi gammaray phenomenology of the millisecond and young pulsars for the entire range of spin-down powers.

112.86 — A hundred stellar winds, some X-rays, and Sgr A* walk into VR …

Christopher M. P. Russell[1]; Miguel Sepulveda[2]; Jorge Cuadra[1]; Q. Wang[3]

[1] *Instituto de Astrofísica, Pontificia Universidad Católica de Chile (Santiago, Chile)*

[2] *Universidad de Chile (Santiago, Chile)*

[3] *University of Massachusetts Amherst (Amherst, Massachusetts, United States)*

The Galactic center is an important target for high energy astrophysics, as exemplified by over 5Ms of Chandra observing time. Our prior work synthesized the thermal X-ray emission from hydrodynamic simulations of 25 Wolf-Rayet stars and their winds orbiting within a parsec of Sgr A*, and well matched the total flux and spectral shape of Chandra XVP data in a 2″-5″ ring around the SMBH. These simulations also pair well with immersive visualizations; our 360-degree video of column density from Sgr A*'s perspective, powered by a Chandra/NASA press release, has a combined YouTube (https://youtu.be/YKzxmeABbkU) and Facebook tally of 1.3 million views. Though 360-degree videos allow the viewer to look over all 4pi sr, they unfortunately fix the viewing location since the movie frames are pre- rendered. Therefore, we are now taking the next step by putting the hydro simulations into virtual reality (VR) so the user has complete control of their location and viewing direction. Though this is naturally a more computationally expensive process, a phone-based VR headset can handle the simultaneous column density and X-ray emissivity calculation for 100K gas cells from a single snapshot as the user traverses the simulation domain in real time, while mimicking the VR experience via a laptop can accommodate a full 2M-particle snapshot with minor lag. (In the future, we aim for room-scale VR with a high-GPU computer to add the time evolution of the simulation as well.) This presentation will show the VR of our latest hydro simulations of the Galactic center, which also incorporate the O and 'S' stars, bringing the total number of massive stellar winds to ∼100. Though the previously explored outer regions have similar X-ray properties, the X-ray flux within a PSF of Sgr A* is appreciably reduced, thereby providing an opportunity to explore the reasoning behind this with the newly developed VR tools. It is also our hope that others with 3D simulations (or observational datasets) are interested in getting their simulations into VR, on which we would be happy to collaborate.

112.87 — The Magnetospheres of Merging Neutron Stars

Constantinos Kalapotharakos[1,2]; Demos Kazanas[2]; Alice Harding[2]; Ioannis Contopoulos[3]; Zorawar Wadiasingh[2]

[1] *University of Maryland, College Park (College Park, Maryland, United States)*

[2] *NASA, Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[3] *Academy of Athens (Athens, Greece)*

Astrophysics has recently entered the multi-messenger era with gravitational wave (GW) detections. The recent neutron star (NS) merger event GW170817 detected by LIGO and Fermi-GBM and the anticipated high rate of detection of similar events makes timely the study of double NS systems. The electromagnetic (EM) signal, detected by Fermi-GBM, followed the GW signal, detected by LIGO, by 1.7sec implying that the physical processes responsible for the EM signal resulted from the NS merging. Nonetheless, in the light of the new era, it is important to explore the possible counterpart EM signals that precede the merging as well as the impact of the pre-merging magnetosphere on the post-merging processes. I will present the structure of double pulsar magnetospheres before the merging event, using macroscopic and kinetic PIC simulations. Our models explore the parameter space (e.g., spin- periods, surface magnetic field strengths, magnetic field polarities, inclination angles) in order to identify the dissipative regions, the corresponding particle acceleration, Poynting-flux patterns and, high-energy emission radiation patterns. Moreover, taking into account the anticipated rate of LIGO GW detections for this class of events, we define the detection limits of preceding EM signals as functions of the model parameters.

112.88 — Exploring TeV and X-ray Connections in Galactic High-Energy Sources: Highlights from VERITAS

Brian Humensky[1]
[1] *Department of Physics, Columbia University (New York, New York, United States)*

The VERITAS observatory studies very-high-energy (VHE) gamma-ray emission from astrophysical sources in the energy range of about 100 GeV to 30 TeV. At these energies, VERITAS has detected 63 VHE sources, and the current catalog of TeV objects includes pulsar wind nebulae, a pulsar, supernova remnants, X-ray binaries, blazars, radio galaxies, and a starburst galaxy. Joint programs between TeV instruments and other telescopes help in understanding the physical processes responsible for the VHE emission in astrophysical sources. In particular, the monitoring of gamma-ray sources in the broad keV range, both in flaring and quiescent states, is critical for understanding the physics of these extreme accelerators since the X-ray and VHE gamma-ray emission is often highly correlated and produced by the same population of electrons. We will explore the connections between VHE astrophysics above 100 GeV and X-rays and present a few recent highlights from VERITAS. We will include results from known Galactic TeV binaries as well as report on the follow up of HAWC sources where the multi-wavelength SEDs could help determine the nature of the unidentified VHE sources.

112.89 — The black hole transient Swift J1858.6-0814: a new V404 Cyg analog?

Jeremy Hare[1]*; John Tomsick*[1]*; Javier A. García*[2]*; Dom Walton*[3]*; Felix Fuerst*[4]*; Aarran Shaw*[5]*; Maica Clavel*[6]*; Andrew Fabian*[3]*; Fiona Harrison*[2]*; Chris L. Fryer*[7]*; Jon Miller*[8]*; Michael Parker*[4]*; Katja Pottschmidt*[9]*; Yanjun Xu*[2]*; Joern Wilms*[10]
[1] *Space Sciences Lab, UC Berkeley (Berkeley, California, United States)*
[2] *Dr. Karl Remeis-Observatory (Bamberg, Germany)*
[3] *California Institute of Technology (Pasadena, California, United States)*
[4] *University of Cambridge (Cambridge, United Kingdom)*
[5] *European Space Astronomy Center (Madrid, Spain)*
[6] *University of Alberta (Edmonton, Alberta, Canada)*
[7] *Institut de Planetologie et d'Astrophysique de Grenoble (Saint-Martin-d'Hères, France)*
[8] *Los Alamos National Laboratory (Los Alamos, New Mexico, United States)*
[9] *University of Michigan (Ann Arbor, Michigan, United States)*
[10] *NASA GSFC & CRESST (Greenbelt, Maryland, United States)*

Swift J1858.6-0814 is a newly discovered Galactic X-ray transient likely hosting a black hole. We report on the results of our NuSTAR observation of the source, which showed large-amplitude flares spanning roughly two orders of magnitude, similar to the flares observed in V404 Cygni during its outburst in 2015. The source's spectrum is well fit by an absorbed (due to the ISM) reflection model, having both relativistic and non-relativistic components, which allows us to place constraints on the physical parameters of the system (e.g., ionization fraction, reflection fraction) and to study how they vary during the episodes of X-ray flaring. We are also able to place constraints on the black hole's spin. Lastly, we will discuss the possibility of obtaining a mass estimate of the black hole once the system returns to quiescence.

112.90 — Supersoft sources without nuclear fusion

Thomas J. Maccarone[1]*; Thomas J. Nelson*[2]*; Peter J. Brown*[3]*; Koji Mukai*[4]*; Philip A. Charles*[5]*; Andry Rajoelimanana*[6]*; David Buckley*[7]*; Jay Strader*[8]*; Laura Chomiuk*[8]*; Christopher T. Britt*[9]*; Saurabh Jha*[11]*; Przemek Mroz*[10]*; Andrzej Udalski*[10]*; Michal Szymanski*[10]*; Igor Soszynski*[10]*; Radoslaw Poleski*[10]*; Szymon Kozlowski*[10]*; Pawel Pietrukowicz*[10]*; Jan Skowron*[10]*; Krzysztof Ulaczyk*[10]
[1] *Department of Physics & Astronomy, Texas Tech University (Lubbock, Texas, United States)*
[2] *University of Warsaw (Warsaw, Poland)*
[3] *Rutgers University (New Brunswick, New Jersey, United States)*
[4] *University of Pittsburgh (Pittsburgh, Pennsylvania, United States)*
[5] *Texas A&M University (College Station, Texas, United States)*
[6] *NASA/GSFC (Greenbelt, Maryland, United States)*
[7] *University of Southampton (Southampton, United Kingdom)*
[8] *University of the Free State (Bloemfontein, South Africa)*
[9] *SAAO (Cape Town, South Africa)*
[10] *Michigan State University (East Lansing, Michigan, United States)*
[11] *Space Telescope Science Institute (Baltimore, Maryland, United States)*

Supersoft sources have long been known to arise from steady nuclear fusion on the surfaces of high accretion rate white dwarfs and during classical novae. Recently, we have discovered a new mechanism for making supersoft emission without nuclear fusion: ultra-high mass transfer rate dwarf novae. The transient ASASSN16-oh in the Small Magellanic Cloud is the first example of this phenomenon, having first been detected as an optical transient too bright to be a typical dwarf nova, and too faint to be a classical nova, and then found to show supersoft emission that appears to have a physical area smaller than the surface of a white dwarf, but consistent with a belt of hot emission either at the inner disk, or around the white dwarf's equator. We discuss the observations and the physics of the accretion flow in this scenario, as well as the implications for understanding supersoft source populations.

112.91 — Fermi LAT Observations of Two Be-Pulsar Binary Systems at GeV Energies

Kent Wood[1]; Tyrel J. Johnson[3]; Matthew Kerr[2]; Chi C. Cheung[2]; Paul S. Ray[2]; Masha Chernyakova[4]

[1] *Praxis, Inc (resident at NRL) (Arlington, Virginia, United States)*

[2] *NRL (Washington, District of Columbia, United States)*

[3] *GMU (Fairfax, Virginia, United States)*

[4] *DCU (Dublin, Ireland)*

A small, but growing, number of binary systems comprising a compact object (neutron star or black hole) orbiting a massive Be or O type star are seen to emit phase-varying, non-thermal radiation from radio waves up to TeV gamma rays. The nature of the compact object is only definitively known in two systems, both comprising a young, rotation-powered pulsar and a Be star. The PSR B1259-63 system has an orbital period of 3.4 years and Fermi has observed 3 periastron passages. Enhanced GeV emission appears after periastron, with the most-recent event, in Autumn of 2017, displaying rapid variability on a timescale of minutes. The only observed periastron in the 50-year-period PSR J2032+4127 system occurred in November of 2017. We will describe GeV observations of both periastron passages. Comparisons will be made with a third well-studied Be star binary system, A0538-66, where the neutron star member has a similarly short spin period known from a transient accretion episode, and with ULX accreting pulsars. Fermi work at NRL is supported by NASA.

112.92 — High Energy Pulsations from PSR J2022+3842

Brent Limyansky[1,2]; Hakura Ohuchi[4]; Lucas Guillemot[5]; Pablo Saz Parkinson[1,3]; David A. Smith[6]; Chin-Ping Hu[7,3]; C.-Y. Ng[3]

[1] *Department of Physics, University of California, Santa Cruz (Santa Cruz, California, United States)*

[2] *Santa Cruz Institute for Particle Physics (Santa Cruz, California, United States)*

[3] *The University of Hong Kong (Hong Kong, Hong Kong)*

[4] *Tokyo Institute of Technology (Tokyo, Japan)*

[5] *CNRS Orleans (Orleans, France)*

[6] *Centre Etudes Nucléaires de Bordeaux Gradignan (Gradignan, France)*

[7] *Kyoto University (Kyoto, Japan)*

PSR J2022+3842 is a young, energetic pulsar with a characteristic age of 8.9 kyr and spin down power 3.0×10^{37} erg s^{-1}. Located in supernova remnant G76.9+1.0, and spatially coincident with a *Fermi* LAT source, pulsations with a period of ~48.6 ms have been reported in radio by the GBT, as well in the X-ray band by *Chandra*, *RXTE*, and XMM- Newton. Large amounts of timing noise typical of young pulsars combined with the radio-faint nature of this pulsar makes deriving a global timing solution that smoothly connects all individual observations challenging. Analysis with the *Fermi* LAT, although complicated by high levels of background in the surrounding Cygnus region, can help bridge these gaps. In this work we present an analysis of data from NuSTAR and NICER showing strong pulsations from PSR J2022+3842 in the 3-79 keV and 0.5-12 keV energy ranges, respectively. Analyzing over 10 years of Pass 8 LAT data at energies > 60 MeV, we confirm a previous tentative detection of this gamma-ray pulsar. Using the combined X-ray, radio, and gamma-ray observations, we study its properties in the context of other young pulsars, with a particular interest in comparing PSR J2022+3842 to soft gamma-ray pulsars.

112.93 — The fundamental plane for GRB X-ray afterglows

Maria Dainotti[1,2]; Shigehiro Nagataki[3]; Xavier Hernandez[4]; Sergey Postnikov[5]; Paul O' Brien[6]; Richard Willingale[6]; Stephanie Striegel[7]

[1] *Astronomical Observatory, Jagiellonian University (Krakow, Poland, Poland)*

[2] *Stanford (Stanford, California, United States)*

[3] *Riken (Wako, Saitama, Japan)*

[4] *UNAM (Mexico, Mexico, Mexico)*

[5] *Indiana University (Bloomington, Indiana, United States)*

[6] *Leicester (Leicester, London, United Kingdom)*

[7] *San Jose State University (San Jose, California, United States)*

Long gamma-ray bursts (GRBs) with a plateau phase in their X-ray afterglows obey a 3D relation, between the rest-frame time at the end of the plateau, T_a, its corresponding X-ray luminosity, L_a, and the peak luminosity in the prompt emission, L_{peak}. This 3D relation identifies a GRB fundamental plane whose existence we here confirm. Here we include the most recent GRBs observed by Swift to define a "gold sample" (45 GRBs) and obtain an intrinsic scatter about the plane compatible within 1σ with the previous result. We compare GRB categories, such as short GRBs with extended emission (SEE), X-ray flashes, GRBs associated with supernovae, a sample of only long-duration GRBs (132), selected from the total sample by excluding GRBs of the previous categories, and the gold sample, composed by GRBs with light curves with good data coverage and relatively flat plateaus. We find that the relation planes for each of these categories are not statistically different from the gold fundamental plane, with the exception of the SSE, which are hence identified as a physically distinct class. The gold fundamental plane has an intrinsic scatter smaller than any plane derived from the other sample categories. Thus, the distance of any particular GRB category from this plane becomes a key parameter. We computed the several category planes with $T_a$as a dependent parameter obtaining for each category smaller intrinsic scatters (reaching a reduction of 24% for the long GRBs). The fundamental plane is independent from several prompt and afterglow parameters.

112.94 — Early Fermi and Swift Observations of GRB 190114C

Donggeun Tak[1,2]; Eric Burns[2]; Julie McEnery[2,1]
[1] *Department of Physics, University of Maryland, College park (Greenbelt, Maryland, United States)*
[2] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

An extremely bright long Gamma-Ray Burst (GRB), GRB 190114C, was detected at 20:57:03 UT on 14 January 2019 (T0) by many observatories, including the Fermi Gamma-ray Space Telescope, the Neil Gehrels Swift Observatory, and the Major Atmospheric Gamma Imaging Cherenkov Telescopes (MAGIC) whose detection is the first of a GRB at very high energies. With strong emission in the GeV regime, GRB 190114C is the best sample for keeping track of the broadband spectral evolution, which was not possible for GRB 130427A due to the saturation of detectors such as Gamma-ray Burst Monitor (GBM). We performed time-resolved analysis on GRB 190114C with Fermi and Swift, covering about ten decades in energy. We present a preliminary analysis of several noteworthy features in the evolution of the spectrum and test possible models to understand these results.

112.95 — Particle-in-cell simulations of pair discharges at pulsar polar caps

Fabio Cruz[2,1]; Alexander Yuran Chen[1]; Anatoly Spitkovsky[1]; Thomas Grismayer[2]; Luis Silva[2]
[1] *Department of Astrophysical Sciences, Princeton University (Princeton, New Jersey, United States)*
[2] *GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico (Lisbon, Lisbon, Portugal)*

When subject to the rotationally induced electric field of pulsar polar caps, electrons and positrons are accelerated along the magnetic field, producing gamma-ray curvature radiation. The emitted gamma-rays, in turn, are absorbed by the magnetic field, converting to new electron-positron pairs. The repetition of this process leads to a cascade of elementary particles that are the source of pulsar magnetospheric plasma. The final number of particles created in pair cascades and their connection with pulsar radio emission remains an open problem. Obtaining numerical models of pulsar pair discharges is a challenging endeavor and one that was only addressed in simplified one- dimensional simulations. In this work, we present two-dimensional particle-in- cell simulations of pair discharges near pulsar polar caps, including the Quantum Electrodynamics effects responsible for gamma-ray and pair production processes from first principles. We use these simulations to study the time dependence and distribution in altitudes and latitudes of pair cascades, underlining the differences to previous models with simplified prescriptions. We analyze the particle spectra and discuss the constraints that our simulations put on pair production rates for use in global pulsar simulations. We also estimate the fraction of gamma-rays that escapes the polar cap and contributes to the flux of polar gamma-rays in Fermi data.

112.96 — ULX spectra revisited: observational evidence of accreting envelopes around magnetized Neutron stars

Georgios Vasilopoulos[1]; Filippos Koliopanos[2]; Olivier Godet[2]; Natalie Webb[2]; Johannes Buchner[3]
[1] *Yale Univestity (New Haven, Connecticut, United States)*
[2] *CNRS/IRAP (Toulouse, France)*
[3] *Pontificia Universidad Católica de Chile (Santiago, Chile)*

Ultra luminous X-ray (ULX) sources are among the most intriguing binary systems, that have long been thought to host the elusive intermediate mass black holes. Remarkably, within the last years there has been undisputed evidence that at least a few of these systems are powered by accreting neutron stars (NS) that are rotating with spin periods close to 1 s. In light of these recent discoveries and recently introduced models placing neutron stars as the engines of ULXs, we revisit the spectra of eighteen well-known ULXs, in search of indications that favor or reject this hypothesis. We find that the notable (>6keV) spectral curvature observed in most ULXs, is commensurate with the Wien tail of a hot (T>1keV) multicolor black-body component and confirm that a double thermal model (comprised of a ”cool” and ”hot” thermal component) with the addition of a faint nonthermal tail describes all ULX spectra in our list. More importantly, we offer a new physical interpretation for the dual thermal spectrum, where it is the result of accretion onto high magnetized NSs rather than black holes, in agreement with theoretical predictions. We estimate the magnetic-field strength and demonstrate that it correlates strongly with the source luminosity and the temperature of the hot component. We also discuss the application of our model on the most recent pulsating ULX ”NGC 300 ULX1”, casting doubts on the claimed presence of a cyclotron scattering feature in its spectrum. Our findings offer an additional and compelling argument in favor of NSs as prime candidates for powering ULXs, as has been also postulated by theory.

112.97 — Kinetic simulations of relativistic turbulence in radiative plasma

Vladimir Zhdankin[1]; Dmitri Uzdensky[2]; Gregory Werner[2]; Mitchell Begelman[2]
[1] *Department of Astrophysical Sciences, Princeton University (Princeton, New Jersey, United States)*
[2] *University of Colorado at Boulder (Boulder, Colorado, United States)*

High-energy astrophysical systems often contain collisionless plasmas that are in a turbulent state, with examples including pulsar wind nebulae, black- hole accretion flows, and jets. It is important to understand the nature and role of turbulence in these systems. We describe recent numerical results on driven turbulence in relativistic pair plasmas, obtained from first-principles particle-in-cell simulations. Specifically, we consider the effect of external inverse Compton radiative cooling of sufficient strength to balance energy injection and maintain a statistical steady state (assuming an optically thin plasma). We study the turbulence statistics and particle distributions across a broad range of magnetizations. Whereas efficient nonthermal particle acceleration occurs in turbulence without radiative cooling (leading to a broad power-law distribution of particle energies), we find that radiative cooling effectively thermalizes the particle population. The resulting quasi- thermal energy distributions are well fit by predictions from stochastic acceleration models. We also find that the distributions of particles, and hence of the emitted high-energy photons, are significantly anisotropic, leading to intermittent beaming that is potentially observable. The anisotropy, spatial inhomogeneity, and temporal variability of high-energy particles become more dramatic at high magnetization, when the turbulent velocity fluctuations approach the speed of light. We discuss the relevance of these results for astrophysical systems.

112.98 — A unified accretion-ejection paradigm for X-ray binaries

Grégoire Marcel[1,2]; Joseph Neilsen[1]; Jonathan Ferreira[2]; Pierre-Olivier Petrucci[2]; Maica Clavel[2]
[1] *Department of Physics, Villanova University (Philadelphia, Pennsylvania, United States)*
[2] *Institut de Planétélogie et d'Astrophysique de Grenoble (Grenoble, France)*

The hysteresis behavior of X-ray binaries during their outbursts remains a mystery. We have developed a paradigm where the disk material accretes in two possible, mutually exclusive, ways: the usual alpha-disk mode and a jet- emitting disk mode, where magnetically-driven jets carry away mass, energy, and all the angular momentum vertically. Within our framework, the transition from one mode to another is related to the magnetic field distribution, an unknown. I recently developed a two-temperature plasma code to self- consistently compute global spectra of the accretion disk for a large ensemble of disk parameters, including the accretion rate and the transition radius between the two accretion modes. I will show how this model can reproduce typical hard states of X-ray binaries up to unprecedented luminosities, and how we can predict 9 GHz radio fluxes for any given set of jet parameters. Strikingly, both spectral features fit extremely well. Playing now on both accretion rate and transition radius, I will show how this method can reproduce all RXTE X-ray spectral shapes and ATCA radio fluxes (9 GHz) from the black hole GX339-4 between 1996 and 2011. This is, to our knowledge, the first time that accretion-ejection cycles have been reproduced using both accretion (X-rays) and ejection (radio) constraints. I will discuss the implications of our results for GX339-4, and I will demonstrate how our method can be applied to AGN and other X-ray binaries, including new observations of MAXI J1535-571 with NuSTAR and NICER.

112.99 — Joint Gamma-ray and Gravitational Wave Searches for Neutron Star Mergers

Eric Burns[1]
[1] *NASA/GSFC (Greenbelt, Maryland, United States)*

On August 17th, 2017 the merging of two neutron stars (NSs) was jointly detected in gravitational waves (GWs) by LIGO and gamma-rays by Fermi GBM. Because of the small intrinsic time offset between these two singles, these events can be searched for together. While GW170817 and GRB 170817A were fully independent detections (after GW data cleaning), this will not always be the case. Joint searches can increase the number of confirmed GW-detections by elevating the significance of subthreshold signals and by independent confirmation of single interferometer detections. Further, the independent localizations can be combined to further constrain the region of interest. This will greatly aid the follow-up effort for GRB afterglow and kilonovae. We will discuss how this can be done, what LIGO and GBM are implementing for the O3 observing run this year, and plans for the future.

112.100 — A Survey of the Spectral Energy Distributions (SEDs) of Southern X-Ray Binaries

Michael L. McCollough[1]*; Saeqa Vrtilek*[1]*; John Dickey*[2]*; John Tomsick*[3]*; Charles Bailyn*[4]
[1] *HEA, CfA (Cambridge, Massachusetts, United States)*
[2] *University of Tasmania (Horbart, Tasmania, Australia)*
[3] *SSL/UC Berkeley (Berkeley, California, United States)*
[4] *Yale University (New Haven, Connecticut, United States)*

To better understand the nature and energy dynamics of X-ray binaries (XRBs) we have undertaken a large multi-wavelength campaign to observe a number southern X-ray binaries. Over the period of roughly a week we made observations in the radio, using the Australia Telescope Compact Array, of ~ 40 X-ray binaries at three different frequencies. We also arranged for observations with Swift (X-ray), RXTE (X-ray), and SMARTS (Optical/IR) to be made during this time period for several of these XRBs (~15). From these observations we have create spectral energy distributions (SEDs) going from the radio to X-ray for several of these X-ray binaries. This survey gives us a look at the total spectral energy distribution and the a measure of the bolometric luminosity of several XRBs. In addition, it gives us a snapshot in time of the state and behavior of a large group XRBs. We will examine and discuss our results.

112.101 — NuSTAR and NICER Observations of X Persei

Michael Thomas Wolff[1]*; Peter Becker*[2]*; Keith Gendreau*[3]*; Paul Britton Hemphill*[4]*; Katja Pottschmidt*[5]*; Kent Wood*[6]
[1] *Space Science Division, Naval Research Laboratory (Washington, District of Columbia, United States)*
[2] *George Mason University (Fairfax, Virginia, United States)*
[3] *NASA/GSFC (Greenbelt, Maryland, United States)*
[4] *MIT (Cambridge, Massachusetts, United States)*
[5] *UMBC (Baltimore, Maryland, United States)*
[6] *Praxis, Inc. (Alexandria, Virginia, United States)*

We report on observations of the X-ray binary system X Persei obtained by NuSTAR andn the NICER instrument on the International Space Station. These observations were close enough in time during December 2018 - January 2019 to be essentially contemporaneous. X Persei is a binary system with an accreting X-ray pulsar (neutron star spin period ~835 seconds) orbiting a Be star in a moderately eccentric orbit (orbital period ~250.3 days). NICER obtained data in the 0.2-12.0 keV energy range and NuSTAR obtained data in the 3-78 keV range. The NICER and NuSTAR observations yield a sampling of the X Persei spectrum across the entire energy range from 0.2 to 78 keV. We investigate the pulse shape as a function of energy across this range. We explore the shape of the spectrum, and in particular the steep continuum spectral power law index indicative of low luminosity, bulk Comptonization-dominated spectral formation. Finally, we explore the possibility of a cyclotron resonant scattering feature near 30 keV and the possibility of an additional broad spectral component above 40 keV.

This work was supported by NASA through the NICER mission, the NASA Astrophysics Explorers Program, and the NASA NuSTAR Guest Investigator Program.

112.102 — Deciphering the short-term variability of clumpy winds in high mass X-ray binaries

Victoria Grinberg[1]*; Michael Allen Nowak*[2]*; Natalie Hell*[3]
[1] *Institute for Astronomy and Astrophysics (IAAT)), Universitaet Tuebingen (Tuebingen, Germany)*
[2] *Washington University (St. Louis, Missouri, United States)*
[3] *LLNL (Livermore, California, United States)*

In high mass X-ray binaries (HMXBs), the black hole or neutron star accretes matter from the wind of a massive supergiant companion. Such winds are strong, with mass loss rates up to 10^{-5} solar masses per year, and highly structured (clumpy); understanding their clumpiness is key to understanding the mass loss from massive stars. The interaction of the emission produced through the accretion onto the compact object with the wind material can be used to study the wind itself, in particular its geometry and small-scale structure. HMXBs are our unique chance to probe individual clumps and clump groups as opposed to the wind as a whole.

Observations of bright sources such as Vela X-1 and simulations of clumpy wind structure show that the absorption in wind-accreting HMXB can change significantly on timescales as short as 10-100 sec and below. Buy such short timescales are not accessible for direct spectroscopy with current instruments and direct measurement of absorption variability will be challenging even for the next generation of X-ray telescopes. However, varying absorption will produce changes in spectral shape that correspond to typical tracks on X-ray color- color-diagrams. Such tracks can, in principle, be used to assess properties of variable absorption, for example to directly estimate wind and clump properties from variability timescales or to define time intervals for absorption-resolved spectroscopy. We have used color-color diagrams to interpret the observed variability as variable partial absorber, and to enable absorption-resolved high-resolution spectroscopy that probes the structure of the clumps, for example in the HMXB Cyg X-1.

But the prediction from a simple neutral absorber and observed tracks in color-color space disagree in exact shape. We thus re-examine assumptions on the ionization structure of the absorbing material and the prediction for the color-color behavior and show that a warm absorber is necessary to explain the observations, i.e. the material of the wind is significantly ionized, either through internal processed or through the interaction with the compact object.

112.103 — Variable cosmic-ray acceleration in η Carinae

Roland Walter[1]; Matteo Balbo[1]

[1] *Department of Astronomy, University of Geneva (Versoix, Switzerland)*

η Carinae is composed of two very massive stars orbiting each other in 5.5 years. The primary star features the densest known stellar wind, colliding with that expelled by its companion. The wind collision region dissipates energy and accelerate particles up to relativistic energies, producing non thermal X- and γ-ray emission detected by Beppo-SAX, INTEGRAL, Swift, Suzaku, Agile, Fermi and H.E.S.S.. The orbital variability of the system provides key diagnostic on the physics involved and on the emission mechanisms. The low- energy component, which cuts off below 10 GeV and varies by a factor < 2 along the orbit, is likely of inverse Compton origin. The high energy component varies by larger factors and differently during the two periastrons observed by Fermi. These variations match the predictions of simulations assuming a magnetic field in the range 0.4-1 kG at the surface of the primary star. The high-energy component and the thermal X-ray emission were weaker than expected around the 2014 periastron suggesting a modification of the inner wind density. Diffuse shock acceleration in the complex geometry of the wind collision zone provides a convincing match to the observations and new diagnostic tools to probe the geometry and energetics of the system. A future instrument sensitive in the MeV energy range could discriminate between lepto- hadronic and hadronic models for the gamma-ray emission. At higher energies, the Cherenkov Telescope Array will distinguish orbital modulations of the high-energy component from these of ultraviolet-TeV photo absorption providing a wealth of information constraining acceleration physics in more extreme conditions than found in SNR.

112.104 — The Orbit of IGR J16493-4348: An Eclipsing Supergiant High-Mass X-Ray Binary Pulsar

Aaron B. Pearlman[1]; Joel B. Coley[4,5]; Robin H. D. Corbet[2,3]; Katja Pottschmidt[5,3]

[1] *Division of Physics, Mathematics, and Astronomy, California Institute of Technology (Pasadena, California, United States)*

[2] *CRESST/Mail Code 662, X-ray Astrophysics Laboratory, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[3] *University of Maryland, Baltimore County (Baltimore, Maryland, United States)*

[4] *Department of Physics and Astronomy, Howard University (Washington, District of Columbia, United States)*

[5] *CRESST/Mail Code 661, Astroparticle Physics Laboratory, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

IGR J16493–4348 is a wind-accreting supergiant high-mass X-ray binary (sgHMXB), where the neutron star is eclipsed by its stellar companion every 6.78 days. It is one of only five wind-fed sgHMXBs in which superorbital modulation has been definitely observed. We present an analysis of the system's X-ray variability and periodic modulation using pointed observations (2.5–25 keV) and Galactic bulge scans (2–10 keV) from the Rossi X-ray Timing Explorer (RXTE) Proportional Counter Array (PCA), along with Swift Burst Alert Telescope (BAT) 70-month snapshot (14–195 keV) and transient monitor (15–50 keV) observations. The orbital eclipse profiles from the PCA scan and BAT light curves are modeled using asymmetric and symmetric step and ramp functions. We obtain an improved orbital period measurement of 6.7828 ± 0.0004 days from an observed minus calculated (O–C) analysis of mid-eclipse times derived from the BAT transient monitor and PCA scan data. No evidence is found for the presence of a strong photoionization or accretion wake. We refine the superorbital period to 20.067 ± 0.009 days from the discrete Fourier transform (DFT) of the BAT transient monitor light curve. A pulse period of 1093.1036 ± 0.0004 s is measured from a pulsar timing analysis using pointed PCA observations spanning ~1.4 binary orbits. We present pulse times of arrivals (ToAs), circular and eccentric timing models, and calculations of the system's Keplerian binary orbital parameters. We derive an X-ray mass function of $f_x(M) = 13.2^{+2.4}{}_{-2.5}\ M_\odot$ and find a spectral type of B0.5 Ia for the supergiant companion through constraints on the mass and radius of the donor. We will also discuss additional parameters describing the system geometry, including the eclipse half-angle and binary inclination angle.

112.105 — The NASA Deep Space Network: A Premier Radio Pulsar Observatory

Aaron B. Pearlman[1]; Walid A. Majid[2,1]; Thomas A. Prince[1,2]; Jonathon Kocz[1]; Shinji Horiuchi[3]; Charles J. Naudet[2]

[1] Division of Physics, Mathematics, and Astronomy, California Institute of Technology (Pasadena, California, United States)

[2] Jet Propulsion Laboratory, California Institute of Technology (Pasadena, California, United States)

[3] CSIRO Astronomy and Space Science, Canberra Deep Space Communications Complex (Tuggeranong, Australian Capital Territory, Australia)

The Deep Space Network (DSN) consists of an array of radio telescopes at three locations (Goldstone, California; Madrid, Spain; and Canberra, Australia), which supports NASA's interplanetary spacecraft missions. When the DSN antennas are not communicating with spacecraft, they provide a valuable resource for a wide range of astronomical studies in the radio band. Each DSN complex is equipped with a 70 m diameter radio antenna and a number of smaller 34 m diameter radio telescopes. These antennas are each outfitted with multiple high-efficiency feeds, highly sensitive cryogenically cooled receivers, and dual (circular) polarization capabilities. In addition, all three sites have been updated with state-of-the-art pulsar processing backends that enable data recording with high time and frequency resolution. The DSN telescopes can perform radio observations at the following standard frequency bands: L-band (centered at 1.5 GHz), S-band (centered at 2.3 GHz), X-band (centered at 8.4 GHz), and Ka-band (centered at 32 GHz). The 70 m radio dish in Canberra is also equipped with a dual beam K-band feed covering 17-27 GHz. These instruments are capable of performing simultaneous, dual band observations with both circular polarizations and are currently being used in various pulsar-related programs, which include high-frequency, ultra-wide bandwidth searches for pulsars in the Galactic Center (GC), high-frequency monitoring of radio magnetars, multifrequency studies of giant pulses from the Crab pulsar, and high-frequency searches for fast radio bursts (FRBs). In particular, these instruments allow for high cadence observations, which are important for tracking changes in the flux densities, pulse profile shapes, spectral indices, and single pulse behavior of radio magnetars, all of which can vary on daily timescales. We will describe the DSN's capabilities and present results from observations of three radio magnetars, PSR J1745–2900, PSR J1622–4950, and XTE J1810–197, and the transitional magnetar candidate, PSR J1119–6127, using the DSN radio telescopes near Canberra, Australia.

112.106 — X-ray emission from AR Scorpii

Jeremy Hare[1]; Oleg Kargaltsev[2]; Bettina Posselt[3]; George Pavlov[3]; Igor Volkov[2]

[1] Space Sciences Lab, UC Berkeley (Berkeley, California, United States)

[2] The George Washington University (Washington, District of Columbia, United States)

[3] The Pennsylvania State University (State College, Pennsylvania, United States)

AR Sco is a binary, with a 3.56 hr orbital period, consisting of an M-dwarf and a magnetic white dwarf with a 117 s spin period. This system is particularly interesting because it shows pulsations of non-thermal (presumably synchrotron) emission produced by relativistic particles, quite similar to rotation powered pulsars. We report on the results of our Chandra observation and our simultaneous NuSTAR and XMM-Newton observations of AR Sco. The spectral analysis in the 0.3-20 keV band shows that the spectrum is dominated by emission from an optically thin plasma with a temperature of about 5 keV, average flux of 3e-12 erg/cm^2/s, and emission measure of about 10^{53} cm^{-3}. This emission is likely produced near the M-dwarf's surface. A contribution from a non-thermal component with a photon index of about 2 is also possible. Pulsations with a beat period of 118 s are detected in the XMM- Newton data, with a pulsed fraction of about 10%. The energy-resolved high- resolution Chandra ACIS images show a hint of extended emission having a few times 10^{15} cm size. A possible explanation for such an extension could be emission from a shocked wind of the fast-spinning magnetic white dwarf.

112.107 — Effects of differing X-ray colors on Color-Color-Intensity diagrams of accreting binaries

Saeqa Vrtilek[1]; Nazma Syeda Islam[1]; Boroson Seth Bram[2]; Dong-Woo Kim[1]
[1] *HEAD, SAO (Cambridge, Massachusetts, United States)*
[2] *Clayton State University (Clayton, Georgia, United States)*

We compare the effects of different X-ray colors (as used in the literature) on the separation of different X-ray binary classes (systems containing black holes or pulsating/non-pulsating neutron stars) and states (hard-low; soft-high, etc.) in a 3-dimensional color-color-intensity space. We use data from a single instrument (MAXI/GSC), extracted in selected energy bands. We find that the position of a given source in the diagram is shifted for different colors but the geometry of the track made by each source through varying states remains similar. The separation of classes that persists despite differing X-ray colors suggests an universality in the physics driving the sources to their location in 3-d space; we suggest that two dominant factors affecting location of a source in CCI space are mass accretion rate and magnetic field strength. For separation of states within a class, clearly colors that extend to higher energies are better for sources with hard states and colors that extend to lower energies are better for sources having soft states. However, we find that certain colors fail to trace the entire track of sources in their soft states, irrespective of the energy range encompassed.

113 — XRISM Poster Session

113.01 — XRISM observations of supermassive black holes

Erin Kara[1]
[1] *Department of Astronomy, University of Maryland / NASA GSFC (College Park, Maryland, United States)*

XRISM (or X-Ray Imaging and Spectroscopy Mission) will revolutionize how we understand accreting supermassive black holes. The Resolve instrument contains a microcalorimeter, which will leave its mark on our understanding of every stage of black hole physics, starting from how cold gas flows in from the ISM of the galaxy, down to the inner accretion flow where matter is effected by the strong gravity of the black hole. This gravitational inflow leads to massive outflows, which may be powerful enough to prevent gas from cooling to form stars, thus effecting the evolution of the host galaxy. In this poster, I outline some of the new science enabled by XRISM and present a few potential observations to demonstrate what can be learned from the microcalorimeter's unprecedented line detection capabilities above 2 keV.

113.02 — XRISM Resolve Simulations of 1E 0102.2-7219 and N132D

Paul Plucinsky[1]
[1] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

The Resolve calorimeter instrument on the JAXA X-ray Imaging and Spectroscopy Mission (XRISM) will provide spectra of extended sources with unprecedented resolution and sensitivity. I present spectral simulations of the brightest supernova remnants (SNRs) in the Large Magellanic Cloud (LMC) N132D and the brightest SNR in the Small Magellanic Cloud (SMC) 1E 0102.2-7219 (hereafter E0102). Both of these sources will be valuable for the in-flight verification and calibration of the low energy response of the Resolve calorimeter and Xtend CCD instruments. The bright lines in the spectra of both objects have been well-characterized by the gratings instruments on XMM-Newton and Chandra. Our standard spectral model for E0102 (developed by the thermal SNRs working group of the International Astronomical Consortium for High Energy Calibration (IACHEC), see Plucinsky et al. 2017) has been used by all operational missions with response to low energy X-rays in order to improve their respective calibrations. The line-rich spectra of both of these objects will be useful for verifying the gain scale, spectral resolution, and effective area of the Resolve instrument derived from the ground calibration in the energy range from 0.5 to 3.0~keV. The Resolve calorimeter data promise new insights into the three dimensional structure of both of these remnants, as indicated by the tantalizing result from the Hitomi SXS spectra of a predominantly red-shifted Fe-K component in N132D (Hitomi Collaboration et al. 2017). The Resolve spectra will be superior to the gratings data for constraining the broadening of emission lines due to bulk velocities in the SNR and for thermal broadening to constrain the

ion temperatures. The Resolve spectra will also provide the most sensitive data for detecting and characterizing fainter features in the spectrum such as those expected from a recombining plasma or charge exchange. Studies such as these will of course be done for the Galactic SNRs where the XARM angular resolution allows the emission from different regions to be spatially resolved.

113.03 — What high resolution imaging spectroscopy with XRISM reveals about the cycle of interstellar dust

Lia Corrales[1]

[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

The high resolution imaging spectroscopic capabilities of XRISM, enabled by micro-calorimeters, will have a high impact for studying extended emission from diffuse gas. Of particular interest will be the properties of the nearby interstellar medium (ISM), which serves as a template for measuring the gas properties in every other galaxy. Yet much about the cycle of metals and dust in the Milky Way is not well understood. For example, what is the role of supernovae in producing and processing dust? Such questions are answered by fully measuring the size distribution and composition of existing interstellar dust, which reveals the formation conditions and eventual fate of dust in harsh environments. Light from bright Galactic X-ray binaries is scattered by interstellar dust, producing a 10-arcminute scale 'halo' image. High resolution spectroscopy of the scattering halo will reveal photoelectric resonances from the intervening dust, revealing grain mineralogy in fine detail. Spectroscopy of dust scattering halos also probes the constituent elements of large dust grains, which are relatively invisible in absorption and inaccessible at other wavelengths. XRISM will thereby provide a leap in our understanding of the origin, phase, and exchange of metals across the interstellar, circumgalactic, and intergalactic medium.

113.04 — The XRISM View of Circumgalactic Gas

Edmund Hodges-Kluck[1]*; Robert Petre*[2]

[1] *Department of Astronomy, University of Maryland (Greenbelt, Maryland, United States)*

[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

The X-ray Imaging and Spectroscopy Mission (XRISM) will be able to measure the temperature, mass, and abundances of hot gas around large galaxies. This gas may make up a significant fraction of the total baryon content, and serves as both a reservoir of fuel for future star formation and a repository of feedback energy and many, if not most, of the metals produced in the lifetime of the galaxy. The non-dispersive Resolve spectrometer will be able to map these quantities out to 25-50 kpc around individual galaxies, including in winds and fountains driven by supernovae, and determine whether (or how much) of starburst superwinds escape galaxies. These maps will enable, for the first time, a detailed comparison of the hot circumgalactic gas to cool and warm clouds. We present a few case studies of what XRISM will accomplish.

114 — Chandra Source Catalog 2.0

114.01 — *Chandra* Source Catalog Release 2.0 - The State of the Art Serendipitous X-ray Source Catalog

Ian N. Evans[1]*; Christopher Allen*[1]*; Craig S. Anderson*[1]*; Jamie A. Budynkiewicz*[1]*; Douglas Burke*[1]*; Judy Chen*[1]*; Francesca Civano*[1]*; Raffaele D'Abrusco*[1]*; Stephen M. Doe*[1]*; Janet D. Evans*[1]*; Giuseppina Fabbiano*[1]*; Danny G. Gibbs*[1]*; Kenny J. Glotfelty*[1]*; Dale E. Graessle*[1]*; John D. Grier*[1]*; Roger Hain*[1]*; Diane M. Hall*[2]*; Peter N. Harbo*[1]*; John C. Houck*[1]*; Jennifer Lauer*[1]*; Omar Laurino*[1]*; Nicholas P. Lee*[1]*; Rafael Martinez-Galarza*[1]*; Michael L. McCollough*[1]*; Jonathan C. McDowell*[1]*; Joseph Miller*[1]*; Warren McLaughlin*[1]*; Douglas L. Morgan*[1]*; Amy E. Mossman*[1]*; Dan T. Nguyen*[1]*; Joy S. Nichols*[1]*; Michael Nowak*[3]*; Charles Paxson*[1]*; David A. Plummer*[1]*; Francis A. Primini*[1]*; Arnold H. Rots*[1]*; Aneta Siemiginowska*[1]*; Beth A. Sundheim*[1]*; Michael S. Tibbetts*[1]*; David W. Van Stone*[1]*; Panagoula Zografou*[1]

[1] *Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

[2] *Northrop Grumman Mission Systems (Cambridge, Massachusetts, United States)*

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

By combining *Chandra*'s sub-arcsecond on-axis spatial resolution and low instrumental background with consistent data processing, the *Chandra* Source Catalog (CSC) delivers a wide variety of uniformly calibrated properties and science ready data products for detected sources over four dex of fluxes. The second major release of the catalog, CSC 2.0, roughly triples the size of the previous catalog to more than 315,000 unique X-ray sources on the sky, allowing statistical investigations of large samples of objects using the catalog, as well as individual source studies.

The sensitivity limit for compact sources in CSC

2.0 is significantly improved by using a two-stage approach that involves co-adding multiple observations of the same field prior to source detection, and then using an optimized source detection method. This combination yields a point source detection threshold of ∼5 net counts on-axis for exposures shorter than ∼15 ks. For each detected X-ray source, the catalog provides a detailed set of properties including the source position and position error ellipse, source extent, multi-band aperture photometry, spectral fits, hardness ratios, and temporal variability measures. The Bayesian aperture photometry code produces robust photometric probability density functions (PDFs) in crowded fields, even for low count detections. CSC 2.0 also adds a Bayesian Blocks analysis of the multi-band aperture photometry PDFs to identify multiple observations of the same source that have similar photometric properties, and therefore can be analyzed simultaneously to improve S/N. The catalog additionally provides FITS data products that are immediately suitable for detailed scientific analysis, including per-field and per-source images, photon event lists, responses, spectra, and light curves.

We describe the content and organization of the catalog in detail, discuss the updates that significantly enhance the scientific utility of CSC 2.0, and demonstrate how the catalog content can be immediately and effectively utilized for scientific investigations.

This work has been supported by NASA under contract NAS 8-03060 to the Smithsonian Astrophysical Observatory for operation of the *Chandra* X-ray Center.

114.02 — Live demo of CSC2 interfaces: from WWT to CSCView

Francesca M. Civano[1]

[1] *HEAD, Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

The Chandra Source Catalog release 2.0 (CSC 2.0) includes hundreds of products per source which are both easy enough to be explored by non X-ray expert scientists (e.g., tables of source properties, spectra) and also extremely useful to the most expert X-ray astronomers (merged events files, exposure maps, PSFs). In this live demo, I will showcase how it is easy to browse the sky to find a match for a given target or field using the WWT to explore the CSC 2.0. I will then move to explore the catalog in more details using the CSCview interface, built to browse the tables and retrive the products associated to the sources and the fields were these were detected.

114.03 — The Chandra Source Catalog version 2.0 Demo: Source Properties, Bayesian Photometry, And Variability.

Juan Martinez Galarza[1]

[1] *Chandra X-ray Center, Center for Astrophysics | Harvard & Smithsonian (Somerville, Massachusetts, United States)*

The version 2.0 of the Chandra Source Catalog (CSC2) offers an unprecedented opportunity for serendipitous discovery in the X-ray sky. By stacking Chandra observations we have significantly improved source detection, and we have been able to detect three times more sources with respect to version 1.0. Most importantly, we have fully characterized each detected source (both at the single observation level and at the stack level) and produced a database containing about 1700 columns of information, split across several tables. In particular, we have used Bayesian formalism to derive posterior probability density functions (PDFs) for the source fluxes in each energy band, and, when available, to group detections of the same source that have a similar flux accord to a Bayesian blocks algorithm. This has allowed us to characterize time-domain aspects of the catalog, such as inter- and intra- observation variability and spectral variability with unprecedented detail. In this interactive demo talk I will provide an overview of the catalog source properties, briefly describe the Bayesian algorithms that we used to produce variability properties, and show users how to use the tools that the CSC2 team has prepared in order to browse and visualize catalog, and how to download our data products. Attendees will be guided through the process of identifying a source in the catalog, listing its properties and visualizing them, as well as obtaining relevant data products from the database. Emphasis will be made on how to link our catalog tools to other data visualization tools such as topcat and DS9.

114.04 — Supporting access and scientific usage of Chandra Source Catalog 2 data products

Raffaele D'Abrusco[1]

[1] *HEA, Center for astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

The second release of the Chandra Source Catalog (CSC2) has measured several hundreds of properties that can be used to characterize the astrometric, morphological, photometric and spectroscopic nature of ∼350,000 X-ray sources. These same properties are also estimated for all distinct detections of each source, both for overlapping, combined and single observations. In order to measure these properties at each level of the CSC2 hierarchical structure, new aggregated and science-ready (spectra, time series, bayesian blocks) data products have been produced. These data products are also made available to user of the catalog through an array of interfaces. In this talk, I will show how CSC2 data products can be efficiently accessed and will discuss a few examples of scientifically interesting applications of such data products that can provide additional insights into the nature of the X-ray sky.

114.05 — A new Hubble Diagram of Quasars from the CSC2 Catalog

Guido Risaliti[1]
[1] *University of Florence, Italy (Sesto Fiorentino, FI, Italy)*

Several thousands of quasars with available optical/UV spectra are present in the CSC2 catalogue. I will show the first results of the systematic analysis of the Chandra X-ray spectra for these quasars.. In particular, I will demonstrate that the X-ray spectral properties and the X-ray to UV relation do not evolve with redshift. As a consequence, quasars can be used as distance indicators. Finally, I will present a Hubble diagram of Chandra quasars and discuss its cosmological implications.

115 — Exploring Time Series Data in High Energy Astrophysics

115.01 — Time series exploration in Python and MATLAB: Unevenly sampled data, parametric modeling, and periodograms

Thomas Loredo[1]*; Jeffrey Scargle*[2]
[1] *Cornell Center for Astrophysics and Planetary Science, Cornell University (Ithaca, New York, United States)*
[2] *NASA Ames Research Center (Mountain View, California, United States)*

This talk will open a Special Session, "Exploring time series data in high energy astrophysics," beginning with a brief survey of emerging software aiming to help astronomers explore and model diverse time series data. We will then describe work from our Time Series Explorer (TSE) project, producing new algorithms and software in Python and MATLAB for exploratory analysis and statistical modeling of time series data. This talk will focus on software for parametric modeling via least squares/maximum likelihood/Bayesian approaches, and some specialized time series tools for handling unevenly sampled and point process data. We will also discuss some persistent misunderstandings about periodograms and Fourier power spectra, which can play multiple roles in parametric and nonparametric analyses of astronomical time series. Additional talks in the session will cover modeling AGN time series with stochastic process models, and modeling periodic, quasiperiodic and aperiodic variability in multichannel spectro-temporal data from X-ray binaries using cospectra and other tools.

115.02 — Time series exploration with Stingray: New tools for spectral-timing analysis of X-ray data

Abigail Stevens[1,2]
[1] *Michigan State University (East Lansing, Michigan, United States)*
[2] *University of Michigan (Ann Arbor, Michigan, United States)*

New ideas about how to analyze time-domain X-ray astronomy data have initiated the "spectral-timing revolution," leading to a surge in developments of analysis techniques. Many individual tools and libraries exist, and some are even publicly available, but what has been lacking is a coherent set for a complete analysis. Stingray is a new community-developed, open-source software package in Python for spectral-timing analysis of astrophysical data. This software package provides the basis for developing spectral-timing analysis tools, while following the Astropy guidelines for modern open-source scientific programming. Our goal is to provide the community with a package that eases the learning curve for state-of-the-art spectral-timing techniques, with a correct statistical framework, to make maximal use of data from NuSTAR, NICER, and potentially STROBE-X and eXTP. In this talk, I will highlight the quasi-periodic oscillation (QPO) modeling and the cospectrum tools in the Stingray library using new NICER and NuSTAR data, respectively. For more information on Stingray, see: http://stingraysoftware.github.io/

115.03 — Modeling time variability of AGN with the CARMA models

Malgosia Sobolewska[1]*; Aneta Siemiginowska*[1]*; Jamie Ryan*[2]
[1] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*
[2] *UCLA (Los Angeles, California, United States)*

AGN emission is variable in all energy bands, from radio to X/gamma-rays. There is evidence that this variability is stochastic in nature. I will present a class of continuous-time autoregressive moving average models (CARMA; Kelly et al. 2014) as a tool to characterize the variability features of AGN light curves across the electromagnetic spectrum. The power spectral density (PSD) of a CARMA model can be expressed as a sum of Lorentzian functions, which makes the method extremely flexible and able to model a broad range of PSDs. The CARMA code is designed to deal with non-uniformly sampled, gappy data sets, and thus it is a perfect tool to quantify the time variability of astronomical time series. It has statistically rigorous foundation as it provides the likelihood function for light curves sampled from CARMA processes and relies on a Bayesian method to infer the probability distribution of the PSD given the measured light curve. In particular, CARMA modeling allows us to infer the PSD frequencies of spectral breaks and/or quasi periodic oscillations, if present. These PSD features are importants imprints of the physical processes generating the variability and/or the physical properties of the regions emitting the variable radiation, such as the region's size and location. I will discuss our most recent results on the time variability of the gamma-ray lightcurves of Fermi/LAT blazars and multiband light curves of the BL Lac object, OJ 287, obtained by utilizing the CARMA models.

200 — ISM & Galaxies

200.01 — Twenty Years of Cas A with Chandra

Daniel Patnaude[1]; Rob Fesen[2]; J. Martin Laming[3]; Jacco Vink[4]

[1] *Smithsonian Astrophysical Observatory (Cambridge, Massachusetts, United States)*

[2] *Dartmouth College (Hanover, New Hampshire, United States)*

[3] *Naval Research Laboratory (Washington, District of Columbia, United States)*

[4] *University of Amsterdam (Amsterdam, Netherlands)*

Cassiopeia A is one of only a handful of young supernova remnants to exhibit time variations in thermal and nonthermal X-ray emission. Here, I will present results from a multiyear effort to study the evolution of this extraordinary object. With observations taken on a nearly yearly timescale, we are able to track the evolution of freshly shocked material as it interacts with the remnant's reverse shock, revealing previously unshocked and unseen ejecta. In addition to the observed changes in emission from shocked material, we also continue to observe fluctuations in nonthermal emission on both large and small spatial scales. I will discuss these observed changes in the context of the nonlinear diffusive shock acceleration of particles brought about by a highly amplified post-shock magnetic field.

200.02 — X-raying galactic feedback in nearby disk galaxies

Q. Wang[1]

[1] *Department of Astronomy, University of Massachusetss Amherst (Amherst, Massachusetts, United States)*

Feedback in galaxies represents the weakest link in our understanding of their formation and evolution. How could X-ray observations help to address this problem? I'll present results from a set of recent studies focused on soft X-ray spectroscopy of diffuse hot plasma in nearby galaxies. We show that a considerable fraction of diffuse soft X-ray emission observed in such galaxies cannot simply arise from collisional processes in hot gas itself, as has been commonly assumed. This is important for understanding the nature of the emission and for correctly inferring the physical and chemical properties of the hot gas. In active star-forming galaxies, part of the soft X-ray emission most likely originates in charge exchange between ions and neutral atoms at the interface between hot and cool gases. In a spheroid, non- equilibrium photo-ionization can be important, depending on recent history AGN activity. The X-ray spectra of hot plasma in the stellar bulge of our neighboring Andromeda galaxy, for example, show evidence for an AGN relic of about half million year old. In addition, scattering of resonance lines can also play a major role in shaping the observed X-ray spectrum and spatial distribution of the emission from diffuse hot plasma. We further demonstrate that modeling the effects of these processes can yield key information about the frequency of AGN activity, as well as the velocity structure of the hot gas and its interface area with cool gas, which could hardly be measured otherwise. Thus future X-ray observing facilities with their greatly improved spectroscopic capabilities will greatly advance our understanding of galactic feedback.

200.03 — NuSTAR Discoverty of a 40 keV High-energy X-ray Source within the Central Parsec of the Galaxy

Shuo Zhang[1]; Kerstin Perez[1]; Jaesub Hong[2]; Betsy Mills[3]

[1] *Kavli Institute, MIT (Cambridge, Massachusetts, United States)*

[2] *CfA (Cambridge, Massachusetts, United States)*

[3] *Brandeis University (Waltham, Massachusetts, United States)*

Soft X-ray observations have revealed that the central parsec of the Galaxy harbors a supermassive black hole, a pulsar wind nebula candidate, a cusp of quiescent black hole systems and complicated diffuse X-ray emission components. NuSTAR's arcminte spatial resolution beyond 10 keV allowed us to investigate what the Galactic center has to offer in the high-energy X-ray band. In this talk, I would like to report our discovery of an unexpedted high-energy X-ray source located at merely 1 parsec from the Galactic center supermassive black hole Sgr A*. This source is most significantly detected as an extended source in 40-50 keV. It spatially coincides with a region showing velocity discontinuum of the slighted ionized gas in the circumnuclear disk. I am going to discuss two possible origins of this high-energy source in the vicinity of Sgr A*: 1) ionization of the circumnuclear disk by X-ray photon outflows from Sgr A* or a nearby pulsar wind nebula; 2) excitation of the circumnuclear disk by MeV-GeV electrons/protons.

200.04 — First Results from the Major XMM-Newton, Chandra and NuSTAR Campaign on the NGC 1313 Galaxy

Dominic James Walton[1]; Ciro Pinto[2]; Rajath Sathyaprakash[3]; Tim Roberts[3]; Michael Nowak[4]; William Alston[1]; Peter Kosec[1]; Erin Kara[5]; Felix Fuerst[7]; Andrew Fabian[1]; Roberto Soria[6]; Hannah Penn Earnshaw[8]; Matthew Middleton[9]; Ryan Urquhart[10]; Matteo Guainazzi[2]; Matteo Bachetti[11]; Fiona Harrison[8]; Daniel Stern[12]; Didier Barret[13]; Natalie Webb[13]; Claude Canizares[14]

[1] *Institute of Astronomy, University of Cambridge (Cambridge, Cambridgeshire, United Kingdom)*

[2] *Curtin University (Perth, Western Australia, Australia)*

[3] *Osservatorio Astronomico di Cagliari (Cagliari, Italy)*

[4] *Jet Propulsion Laboratory (Pasadena, California, United States)*

[5] *CNRS (Toulouse, France)*

[6] *Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*

[7] *ESTEC (Noordwijk, Netherlands)*

[8] *Durham University (Durham, County Durham, United Kingdom)*

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

[10] *University of Maryland (Washington DC, District of Columbia, United States)*

[11] *University of the Chinese Academy of Sciences (Beijing, China)*

[12] *ESAC (Madrid, Spain)*

[13] *California Institute of Technology (Pasadena, California, United States)*

[14] *University of Southampton (Southampton, United Kingdom)*

Throughout 2017 we undertook a major, multi-epoch observing campaign on the NGC 1313 galaxy, combining XMM-Newton (800 ks), Chandra (500 ks) and NuSTAR (500 ks). NGC 1313 is notable for hosting two extreme (Lx,peak ~ 1e40 erg/s) ultraluminous X-ray sources (ULXs), X-1 and X-2. Furthermore, X-1 is the first ULX in which absorption in an ultrafast (~0.25c) outflow was been detected. I will present early results from this large coordinated campaign. These include the unusual broadband continuum variability seen in X-1 and the changes/variability seen in its extreme wind, and also the likely discovery of another member of the elusive population of ULX pulsars, remarkable sources in which extreme super-Eddington accretion must be occuring.

200.05 — Hot Gaseous Halos Around L* Galaxies from S-Z Measurements

Joel N. Bregman[1]; Edmund Hodges-Kluck[2,1]; Zhijie Qu[1]; Jiangtao Li[1]

[1] *Department of Astronomy, University of Michigan (Ann Arbor, Michigan, United States)*

[2] *Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The Sunyaev-Zel'dovich effect, commonly seen around galaxy clusters, has been detected around large stacks of massive galaxies (>4L*). We show that the signal should also be visible around nearby L* galaxies due to their larger size and, from Planck SZ maps, we studied the signal for a dozen L* galaxies with 2 Mpc < D < 10 Mpc. A few individual galaxies are detected but the signal is more robust when they are stacked (5-6sigma), where the median signal is detected to at least 150 kpc and implying a gas mass of approximately 7E10 Msun to R_{200}. This is a mass comparable to the stellar component, but less than the missing baryons. If extended to 1.5-2R_{200}, it would account for the missing baryons.

200.06 — Zooming In on Distant Star-Formation: Strong Lensing Assisted Observations of X-Ray Emission From Young Stellar Populations at Cosmic Noon

Matthew Bayliss[1]; Michael McDonald[1]; Keren Sharon[2]; Michael Gladders[3]; Michael Florian[4]

[1] *Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology (Cambridge, Massachusetts, United States)*

[2] *University of Michigan (Ann Arbor, Michigan, United States)*

[3] *University of Chicago (Chicago, Illinois, United States)*

[4] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

Deep X-ray observations of the most highly magnified, strongly lensed galaxies remain an unexplored frontier in high energy astrophysics. I will describe new efforts to detect, and spatially resolve, the X-ray emission associated with ongoing star formation in existing Chandra observations of highly magnified strongly lensed galaxies. Typical high-magnification systems feature a starburst galaxy at z∼1-3 that is magnified by a factor of 20x, or more. For this these systems the Chandra PSF would be magnified into physical resolutions of ∼400-600 parsecs, sufficient to resolve individual large star- forming regions in distant starburst galaxies. In combination with other multi-wavelength data—including rest-frame optical and UV imaging and spectroscopy from Hubble and ground-based telescopes—X-ray observations of bright giant arcs would provide new constraints on the properties of the stellar populations in distant starburst galaxies, especially the high mass stars and the high end of the initial mass function. Moreover, the ∼400-600 parsec spatial resolution would allow us to distinguish differences in the X-ray properties of different star forming regions, which themselves can span a wide range in metallicity, age, and stellar mass. Deep X-ray data on the most highly magnified lensed galaxies would pioneer a new way of studying star formation during the era when most of the Universe's stars formed, effectively previewing the ability of a next generation X-ray mission to study star formation in individual sources in the distant universe.

201 — Fermi at 10

201.01 — Ten Years of Pulsar Discovery with Fermi

Matthew Kerr[1]
[1] *US Naval Research Laboratory (Washington, District of Columbia, United States)*

Fermi data have revealed pulsations from over 250 pulsars, surpassing all but the most optimistic pre-mission predictions. Contributing to this impressive sum are: radio-quiet pulsars found with cutting edge computational techniques; heavily-obscured short period binary millisecond pulsars; very gamma-faint radio pulsars; stably spinning millisecond pulsars; and "garden variety" energetic young pulsars. Each of these groups has advanced our understanding of the birth, evolution, and nature of pulsars. We now know that much of the gamma-ray emission arises from outside the magnetosphere; that plasma-shrouded binary pulsars are common in the Galactic field; and that the gamma-ray "death line" is real. In this talk, I will review these and other highlights and then look forward the next 10 years of discovery.

201.02 — Breakthroughs from Fermi in Cosmic Energetic Particles

Tonia Venters[1]
[1] *Astrophysics Science Division, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

Fermi's view of the high-energy gamma-ray sky has revealed that energetic particles are ubiquitous in the cosmos and play a substantial role in cultivating a variety of astrophysical phenomena. The last ten years of Fermi has led to enormous breakthroughs into the century-old questions surrounding cosmic rays and the newfound mystery of the origins of astrophysical neutrinos. In this talk I will provide highlights of Fermi's contributions to the current landscape of our understanding of these energetic particles and set the stage for our continuing pursuit of solutions to their persistent mysteries.

201.03 — 10 Years of GRBs with Fermi: Problems, Progress & Prospects

Bing Zhang[1]
[1] *UNLV (Las Vegas, Nevada, United States)*

I will discuss a list of open questions in GRB physics and review how the observations with Fermi LAT and GBM helped to (partially) answer these questions, which include jet composition, energy dissipation, particle acceleration and radiation mechanisms, as well as the central engine and progenitor of both long and short GRBs. Future prospects of the GRB science in the multi-messenger era will be also discussed.

202 — Plenary Talk: A Tribute to Riccardo Giaconni & the History of HEAD

202.01 — A Tribute to Riccardo Giacconi

Christine Jones[1]
[1] *Harvard Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

Riccardo Giacconi pioneered the study of the Universe through X-ray observations of the Cosmos, from the development and operation of the first X-ray satellite, Uhuru, to his roles in both the Einstein Observatory and the Chandra X-ray Observatory. He left enduring imprints on both our knowledge of the Universe and on astronomical facilities, including the Harvard-Smithsonian Center for Astrophysics, the Space Telescope Science Institute (STScI), where he was the first director, then as the Director General of the European Southern Observatory, and finally as President of Associated Univerisities (AUI), guiding the expansion of the VLA, while also building ALMA (with ESO and Japan). Riccardo summerized his career "I am greatful to live in this heroic era of astronomy and to have been able to participate and contribute to its evolution." In this talk, I will attempt to share some of Riccardo's accomplishments as well as my personal experiences in working with him on the Uhuru and Einstein X-ray missions.

202.02 — High Energy Astrophysics before HEAD

Virginia Trimble[1,2]
[1] *Department of Physics & Astronomy, U California Irvine (Irvine, California, United States)*
[2] *Queen Jadwiga Observatory (Rzepiennik Biskupi, Poland)*

HEAD, the High Energy Astrophysics Commission of the IAU, and the APS Division of Cosmic Physics were born in a tight temporal cluster, preceded by 5-15 years by the Texas Symposium on Relativistic Astrophysics, the IAU Commission on Astronomy from Space, and the organization that eventually became the International Committee (then Society) on General Relativity and Gravitation (yes, I belong or have belonged to all or their successors). Initially most focussed on sources or events that radiated total energy or luminosity greatly in excess of what came from standard stars and galaxies (with a later shift to high energy per photon or particle, rather than high energy per event or source) and that typically required physics beyond Newton, Maxwell, and Rutherford for their understanding. But the roots go event deeper, with multiple connecting threads. My own efforts date back to the beginning, with a 1967 paper "under" Jesse Leonard Greenstein on "The Einstein Redshift of White Dwarfs" (which increased the number of sources with GR-ish effects from about 3 to 50) and a 1969 paper with Kip Stephen Thorne on "Spectroscopic Binaries and Colllapsed Stars" (now called neutron stars and black holes, and no we didn't find any then, though the method adopted soon led to the recognition of Her X-1 and Cyg X-1 as examples of each). Extended controversy about the reality, energy transport properties, sources, and detectability of gravitational radiation is also part of the story. The talk will aim at filling in as many of these tales (and sometimes tails) as there is time for.

203 — Mission & Instruments I

203.01 — The gamma-ray sky at the highest energies - recent results from HAWC

Henrike Fleischhack[1]
[1] *Department of Physics, Michigan Technological University (Houghton, Michigan, United States)*

Cosmic accelerators such as supernova remnants and active galactic nuclei accelerate particles (electrons, protons, and nuclei) to much higher energies than terrestrial particle accelerators. Yet, much remains unknown about the mechanisms and sites of particle acceleration, as well as their transport inside and outside of galaxies. These energetic particles reveal themselves through non-thermal emission from radio to gamma-ray energies as they interact with matter, radiation fields, or magnetic fields near their sources or elsewhere in the Galaxy. The highest end of the spectrum, the Very-High-Energy (VHE, E>100 GeV) regime, is currently best accessed by ground-based gamma- ray instruments. The field of ground-based gamma-ray astronomy, including IACTs and particle arrays, has seen great improvements over the last decades. The High-Altitude Water Cherekov (HAWC) observatory is a VHE gamma-ray observatory in Mexico, surveying the northern gamma-ray sky above 300 GeV. HAWC was recently expanded to include a sparse array of 'outrigger' detectors, increasing its resolution and detection efficiency at high energies. With the upgrade, the effective collection area above 10 TeV was increased by a factor of 4. With more than three years of data collected so far, HAWC has already made several surprising discoveries, such as such as a population of middle- aged pulsars with extended gamma-ray 'halos' (Geminga and Monogem being the first ones to be discovered), consistent with inverse Compton emission of electrons diffusing away from acceleration regions near the pulsars, and the discovery of gamma-ray emission from the lobes of the micro-quasar SS433. I will show updated results from these studies and highlight other recent measurements of galactic and extragalactic gamma-ray emitters by the HAWC observatory, including a unique view of the gamma-ray sky above 100 TeV.

203.02 — Studying the Crab Nebula with the Compton Spectrometer and Imager

Clio Sleator[1]*; Jacqueline Beechert*[1]*; Steve Boggs*[2]*; T. J. Brandt*[3]*; Hadar Lazar*[1]*; Carolyn Kierans*[3]*; Jarred Matthew Roberts*[2]*; John Tomsick*[1]*; Andreas Zoglauer*[1]

[1] Space Sciences Lab, UC Berkeley (Berkeley, California, United States)
[2] UC San Diego (San Diego, California, United States)
[3] NASA GSFC (Greenbelt, Maryland, United States)

The Compton Spectrometer and Imager (COSI) is a balloon-borne, soft gamma- ray (0.2-5 MeV) telescope designed to study astrophysical sources, including compact objects. COSI utilizes a compact Compton telescope design with 12 germanium detectors and is inherently sensitive to polarization. In May 2016, COSI was launched from Wanaka, New Zealand and completed a successful 46-day flight on NASA's Superpressure balloon. The Crab Nebula is among the sources detected during the 2016 flight. We present an update on our spectral analysis of the Crab. We have constructed an accurate instrument model as required for the response matrix and are able to fit COSI spectra in XSPEC. We have developed a model of the atmosphere above COSI to include in our spectral fits. To perform the background subtraction, we carefully reject background events using a data space for Compton telescopes pioneered by COMPTEL. We will present this background subtraction technique and the resulting Crab spectrum. We will also present our preliminary polarization analysis of the Crab.

203.03 — Laboratory benchmarks for collisional excitation cross sections of K-shell transitions in Fe group elements

Natalie Hell[1]; Greg V. Brown[1]; Peter Beiersdorfer[1]; Richard Kelley[2]; Caroline A. Kilbourne[2]; Maurice A. Leutenegger[2]; Thomas E. Lockard[1]; F. Scott Porter[2]; Makoto Sawada[3,2]
[1] Lawrence Livermore National Laboratory (Livermore, California, United States)
[2] NASA-GSFC (Greenbelt, Maryland, United States)
[3] University of Maryland Baltimore County (Baltimore, Maryland, United States)

Electron impact excitation (EIE) is the dominant line formation process in collisional plasmas. Accurate EIE cross sections are therefore crucial for, for example, temperature sensitive line ratios and for accurate predictions of expected line strengths as a probe for "missing" flux from resonant scattering. K-shell transitions in Fe-group elements provide important diagnostics in energetic, collisional sources such as supernova remnants and clusters of galaxies. As shown by observations with Hitomi-SXS, their diagnostic potential will increase even further with upcoming X-ray missions providing high spectral resolution in the Fe K band such as XRISM and Athena. Using the Lawrence Livermore National Laboratory's electron beam ion trap EBIT-I and the NASA/GSFC EBIT Calorimeter Spectrometer (ECS) we measure the absolute X-ray emission cross sections of K-shell transitions in highly charged ions of Fe-group elements. The excitation cross sections are brought to an absolute scale by normalizing the observed flux of the directly excited lines to the simultaneously measured emission lines from radiative recombination, whose cross sections are well known. The measured cross sections are then used to benchmark theoretical cross sections.

This work was supported by LLNL under Contract DE-AC52-07NA27344 and by NASA grants to LLNL and NASA/GSFC.

203.04 — The Importance of Fermi GBM in the Era of Gravitational-Wave Astronomy

Adam Goldstein[1]
[1] USRA (Huntsville, Alabama, United States)

The Fermi Gamma-ray Burst Monitor (GBM), with observing duty cycle of ~85%, surveys the entire sky that is not occulted by the Earth from 8 keV - 40 MeV with 2 microsecond temporal resolution and data downlinks of each individual photon count. Due to these characteristics, Fermi GBM is currently the most prolific detector of the prompt emission of short-duration gamma-ray bursts (GRBs), some of which are produced by binary neutron star mergers, as confirmed by the realtime simultaneous triggers of GBM and LIGO of GW170817/GRB 170817. The wealth of near-realtime data by the 14 independent detectors on GBM, with fine time and spectral resolution and the ability to localize signals, has enabled GBM to perform powerful subthreshold searches for weak signals coincident with sub-threshold gravitational-wave signals. I will detail the results from these sub-threshold searches during LIGO's first observing run (O1), including the detection of the weak transient GW150914-GBM, discuss the detection of GW170817 and improvements to the sub- threshold searches during O2, and describe the plans and contributions by GBM to GW astrophysics during O3. I will also present results of archival searches of GBM data to estimate the detection rate of events with similar characteristics to GRB 170817A.

203.05 — The BurstCube Experiment

Isabella Brewer[1]
[1] Department of Physics, University of Maryland, College Park (University Park, Maryland, United States)

The BurstCube CubeSat is a 6U (10 × 20 × 30 cm) satellite, scheduled for launch in 2022, that will increase sky coverage to detect gamma-ray bursts (GRBs) and complement currently operating missions such as Swift and Fermi. The primary science goal of BurstCube is to detect and characterize the electromagnetic counterparts of gravitational waves, such as short GRBs. BurstCube will improve sky coverage and localization for GRBs; this will be done by BurstCube's four CsI scintillators. The scintillators are read out using silicon photomultipliers rather than traditional photomultipliers like those used in Fermi-GBM. This contribution will detail the hardware and software developments, with simulated data generated with the Medium Energy Gamma-ray Astronomy library (MEGAlib).

203.06 — First Results from HaloSat

Philip Kaaret[1]
[1] *Department of Physics and Astronomy, University of Iowa (Iowa City, Iowa, United States)*

HaloSat is the first CubeSat for astrophysics funded NASA's by Science Mission Directorate. HaloSat's goal is measure the baryonic mass of the Milky Way's halo by performing an all-sky survey of line emission from highly ionized oxygen. This will help determine if hot halos with temperatures near a million degrees bound to galaxies make a significant contribution to the cosmological baryon budget. Halosat has CCD-like energy resolution and a large grasp that makes it competitive with major missions for observations of diffuse X-ray emission. HaloSat was deployed from the International Space Station in mid-July and began routine science operations in October. We present initial scientific results, including observations of the Cygnus loop and Crab Nebula that demonstrate instrument performance and selected high latitude regions.

204 — GW170817 and Beyond

204.02 — Electromagnetic monitoring of GW sources: Open questions and future facilities

Raffaella Margutti[1]
[1] *Northwestern University (Evanston, Illinois, United States)*

In this talk I will review the still-open questions related to the first NS-NS merger with multi-messenger observations across the electromagnetic spectrum and with gravitational waves. In particular I will concentrate on: (i) the nature of the remnant; (ii) the geometry and physical properties of the outflows lunched by the merger. I will then discuss how future observing facilities might help finding an answer to these questions.

205 — High Throughput Multi-band Spectral Timing

205.01 — The Spectral-Timing Toolbox

Abigail Stevens[1,2]
[1] *Michigan State University (East Lansing, Michigan, United States)*
[2] *University of Michigan (Ann Arbor, Michigan, United States)*

X-ray spectral-timing analysis seeks to investigate how matter behaves in the strong gravitational fields around compact objects. By simultaneously examining the spectral and temporal properties of the emission, we can deduce underlying causal relationships between the different emitting components. Spectral-timing analysis is founded in the understanding that photon arrival time and photon energy should not be analyzed separately, since they are intrinsically connected by the underlying physics. Techniques like energy- dependent time lags of X-ray variability and phase-resolved spectroscopy of rapid quasi-periodic oscillations have led to breakthroughs in our understanding of corona geometry, disk-jet interactions, and the possible origin of QPOs. In this talk, I will review the Fourier underpinnings of spectral-timing analysis and showcase examples of spectral-timing techniques with data from RXTE, XMM, NuSTAR, and NICER.

205.02 — X-ray reverberation studies of the extreme environments around black holes

Daniel Wilkins[1]
[1] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University (Stanford, California, United States)*

From the reverberation of X-rays off the innermost regions the accretion disc, a three-dimensional picture is starting to emerge of the extreme environments around black holes; the structure of the disc and the corona that produces intense X-ray emission, as well of how the launching sites of jets may be connected to the corona and inner disc.

Spectral timing analysis of accreting black holes, compared to the predictions of general relativistic ray tracing simulations, enables the structure of the corona and accretion disc to be mapped. We discover how the corona evolves on long and short timescales, giving rise to orders of magnitude variation in luminosity. X-ray reverberation studies are revealing, for the first time, structure within the corona including a persistent collimated core akin to the base of a jet, even in radio-quiet sources, alongside a second component associated with the accretion disc itself.

This gives us important insight into the small-scale processes close to the event horizon that black holes to power some of the most luminous objects in the Universe, launch vast jets at close to the speed of light and play their important feedback role in the formation of structure in the Universe.

205.03 — Spectral Mapping of Black Hole Accretion Disks at Critical, Fast Timescales

James F. Steiner[1]
[1] *MIT Kavli Institute (Cambridge, Massachusetts, United States)*

Galactic X-ray binaries are the brightest available laboratories for studying strong gravity. Crucially, X-ray binaries are also dynamic systems, with a typical transient binary exhibiting months-long outbursts interspersed with decades of quiescence. During outburst, a typical X-ray binary evolves through a range of accretion states and luminosities, reaching its Eddington limit. The importance of monitoring these brightest systems has been most readily demonstrated through the paradigmatic advancments achieved with spectral-timing breakthrough mission RXTE, which now set the foundation by which X-ray binary systems are understood. This spectral-timing legacy is being advanced through the ongoing NICER and ASTROSAT missions. As two prominent and salient examples of the scientific gains associated with advancements in spectral-timing capabilities, continuum spectral models of the brightest X-ray binary systems have been used to produce constraints on neutron-star equation of state and measurements of black hole spin. A generational successor spectral-timing instrument such as STROBE-X, will revolutionize our understanding of the accretion process as dramatically as did RXTE. Through its large collecting area and high time resolution, our ability to *fully* mine the wealth of information carried by our Galactic sources by reaching the last remaining critical timescales, can be achieved. At the limits of current capabilities, we are now able to spectrally probe the viscous timescale at the innermost edge of the accretion disk; a generational advance will reach *thermal* and *dynamical* timescales! Reachign these high count rates will enable direct spectral study of the structural changes which occur over cycles of quasi-periodic oscillations (QPOs), for even the fastest QPOs. This is essential in order to reveal the physical driving mechanisms of these oscillations, and of particular importance given the widely-held expectation that high-frequency QPOs in stellar-mass black holes (at hundreds of Hz) should be the highest precision markers of black- hole spin.

205.04 — Multi-Wavelength Fast Timing in X-ray Binaries

Alexandra Tetarenko[1]
[1] *East Asian Observatory (Hilo, Hawaii, United States)*

Time domain analysis is a powerful tool with which to study accretion and jet physics near compact objects. Through detecting and characterizing rapid flux variability in X-ray binaries across a wide range of frequency/energy bands (probing emission from different regions of the accretion flow and jet), we can measure properties that are difficult, if not impossible, to measure by traditional spectral and imaging methods (e.g., size scales, geometry, jet speeds, the sequence of events leading to jet launching). While variability studies in the X-ray bands are a staple in the X-ray binary community, there are many challenges that accompany such studies at longer wavelengths. However, with recent advances to observing techniques/instrumentation, the availability of new computational tools, and todays improved coordination capabilities, we are no longer limited by these challenges. In this talk, I will review recent advances in multi-wavelength fast timing observations of X-ray binaries, including the OIR, sub-mm, and radio bands, showing how we can connect variability properties to internal jet physics. Additionally, I will discuss future prospects for obtaining more of these invaluable data sets.

300 — XMM at 20

300.01 — Hot baryons hidden in the universe: XMM-Newton Achievements and Perspectives.

Fabrizio Nicastro[1]
[1] *Osservatprio Astronomico di Roma, INAF (Monte Porzio Catone, Roma, Italy)*

It has been known for decades that the observed number of baryons in the local Universe falls about 30-40% short of the total number of baryons predicted by Big-Bang Nucleosynthesis, inferred by density fluctuations of the Cosmic Microwave Background and seen during the first 2-3 billion years of the universe (redshift z>2-3) in the so called "Lyman-α Forest". While theory provides a reasonable solution to this paradox, by locating the missing baryons in hot and tenuous filamentary gas in-and-around galaxies, it also sanctions the difficulty of detecting them because their by far largest constituent, hydrogen, is mostly ionized and therefore virtually invisible in ordinary signal-to-noise Far-Ultraviolet spectra. Indeed, despite the large observational efforts, only a few marginal claims of detection have been made so far. Here I will first review the observational efforts pursued over the past 15 years by several groups and will then present our recent results that show that the missing baryons should indeed be found in a tenuous warm-hot and moderately enriched medium that traces large concentrations of galaxies and permeates the space between and around them. The detection of these baryons is hampered by foreground ISM contamination, which is hard to correct for, due to our poor knowledge of inner-shell resonant transitions from metals in the X-ray band. In my talk I will suggest a number of observational and experimental strategies to be pursued over the next decade with current facilities, to overcome these intrinsic difficulties, clearly identify locations and physical state of these baryons and pave the way to the deeper and systematic studies that will be enabled by the next generation of high- resolution X-ray integral-field spectrometers.

300.02 — History of Accretion: XMM-Newton Achievements and Perspectives

W. Nielsen Brandt[1]
[1] *Department of Astronomy & Astrophysics, Penn State University (University Park, Pennsylvania, United States)*

XMM-Newton cosmic surveys over the past two decades have played a critical role in transforming our understanding of growing supermassive black holes (SMBHs) in the distant universe. I will briefly review some of the key XMM- Newton advances on the active galactic nucleus (AGN) population and its evolution, the physical processes operating in AGNs, and the interactions between AGNs and their environments. Thankfully, XMM-Newton's health remains robust, and thus we can look forward to many future XMM-Newton survey observations. In this respect, I will describe the ongoing 12 deg^2 XMM-SERVS survey which is covering three legacy sky regions at 50 ks depth: the SERVS areas of W-CDF-S, XMM-LSS, and ELAIS-S1. These regions have first-rate multiwavelength coverage already and are LSST/DES deep-drilling fields, MOONS massive spectroscopy fields, and prime ALMA fields. When the survey and the follow-up of its 12000 X-ray sources are complete, XMM-SERVS should dramatically advance studies of SMBH growth across the full range of cosmic environments, links between SMBH accretion and host-galaxy properties, groups/clusters at z = 0.1-2, protoclusters, and other topics. I will conclude by describing some significant unresolved questions in X-ray surveys research and prospects for advancing the field with aggressive new projects.

300.03 — 20 years of X-ray Exoplanet Observations

Scott Wolk[1]
[1] *High energy, Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

The first exoplanets were discovered in the years leading up to the launch of XMM-Newton. This was well after the design had been completed. Further, the effect of XUV photons on possible exoplanets had hardly been considered when XMM-Newton launched. Nonetheless, XMM-Newton has been instrumental in informing our understanding of exoplanets, their atmospheres, habitable zones and how they interact with their host stars. In this presentation I highlight the contributions to exoplanet science made by XMM-Newton (sometimes in collaboration with the Chandra X-ray observatory) over the last two decades. This research has included many individual exceptional system such as CoRoT-2, HD17156 and GJ436. Conversely, So many X-ray bright exoplanet hosts have been identified that statistical analysis, such the distribution of exoplanet masses in the presence of X-ray irradiation, are possible. As an example I discuss results that suggests that planet atmospheres have been eroded by their host star coronal emissions (e.g. Sanz-Forcada 2010, Owen & Lai 2018). I finish with a discussion of prospects for observations with XMM- Newton over the next decade and with future missions.

300.04 — Relativistic reverberation mapping with XMM-Newton: Achievements and Perspectives

Christopher Reynolds[1]
[1] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*

The inner accretion disk in moderate-to-high accretion rate black hole systems is continually subject to irradiation by the rapidly varying X-ray corona. The spectrum of the reprocessed X-rays, and the echo time-delays (reverberation) characterising this reprocessed emission provides our most powerful too to date for understanding the immediate environment of accreting black holes, and hence nature's most powerful engines. In this talk, I will describe the state-of-the-art in these reverberation studies. I will end by addressing future prospects, with from new instrumentation and next-generation data-analysis techniques.

301 — AGN II

301.01 — Venturing beyond the ISCO: Probing the black hole plunging region

Daniel Wilkins[1]; Chris Reynolds[2]
[1] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University (Stanford, California, United States)*
[2] *University of Cambridge (Cambridge, United Kingdom)*

The immediate vicinities of black holes represent some of the most extreme environments in the Universe, where accreting material in its final moments before plunging through the event horizon powers some of the most luminous sources in the Universe; bright X-ray emitting coronae and vast jets launched close to the speed of light. General relativity predicts that in close proximity to the black hole, within the innermost stable circular orbit (ISCO), gravity is sufficiently strong that stable circular orbits cannot exist and upon reaching this radius, material within the accretion disc must plunge into the black hole. In recent years, the advent of X-ray timing studies has revealed unprecedented amounts of information about the extreme environments around black holes. In particular the detection of the coronal X-ray emission reverberating off the inner regions of the accretion disc has revealed the geometry and the dynamic nature of the corona. The next step is to detect the material within the ISCO and understand its dynamics as it plunges into the black hole. Analysis typically assumes that no X-rays are detected from material within the ISCO. General relativistic ray tracing simulations, however, show how signatures of material inside the ISCO, plunging into the black hole are manifested in observations of X-ray reverberation. Simulations reveal how emission specifically reverberating off of material in the plunging region may be detected with the next generation of X-ray observatories such as Athena, and specialized X-ray timing missions such as STROBE-X. The ability to directly detect the presence of an innermost stable orbit and plunging region would provide a unique test of general relativity in the strong field limit, only accessible around black holes and would be an important component in validating black hole spin measurements. Probing the dynamics of material in the plunging region will reveal how the accretion flow behaves in its final moments and how it may launch jets, accelerate coronae and power some of the most extreme systems in the Universe.

301.02 — NICER observing campaign of the AGN 1ES 1927+654 following a recent transient event

Michael Loewenstein[1,2]; Erin Kara[1,2]; Ronald Remillard[3]; Keith Gendreau[2]; Zaven Arzoumanian[2]; Iair Arcavi[4]; Benny Trakhtenbrot[4]; Claudio Ricci[5,6]; Andrew Fabian[7]; Chelsea Macleod[8]; Diego Altamirano[9]; Edward Cackett[10]; Dheeraj Ranga Reddy Pasham[3]; James F. Steiner[3]; Kent Wood[11]
[1] *Department of Astronomy, University of Maryland (Greenbelt, Maryland, United States)*
[2] *Wayne State University (Detroit, Michigan, United States)*
[3] *Praxis, Inc (Washington DC, District of Columbia, United States)*
[4] *NASA/GSFC (Greenbelt, Maryland, United States)*
[5] *MIT (Cambridge, Massachusetts, United States)*
[6] *Tel Aviv University (Tel Aviv, Israel)*
[7] *Universidad Diego Portales (Santiago, Chile)*
[8] *KIAA (Beijing, China)*
[9] *University of Cambridge (Cambridge, United Kingdom)*
[10] *Harvard, CfA (Cambridge, Massachusetts, United States)*
[11] *University of Southampton (Southampton, United Kingdom)*

We report on NICER X-ray follow-up observations of the remarkable nuclear transient AT2018zf (ASASSN-18el) associated with the changing-look Seyfert galaxy 1ES 1927+654. Results from our detailed NICER time-resolved spectral analysis reveal a spectrum dominated by a very soft (∼100 eV) blackbody-like component, but with excess emission around 1 keV – characteristics very different from those of any previous observation of this source. NICER has been monitoring 1ES 1927+654 with 1-3 day cadence starting ∼80 days after the ASAS-SN flare detection, during which the X-ray emission - in addition to rapid variability on timescales from 10 ks to 500 seconds – has undergone a rapid decline of two orders of magnitutude, extended period of quiescence, and re-brightening to fluxes comparable to those following the initial flare. Despite the intense flaring on timescales of hours to days, the ensemble of exposures appear to follow a simple track in spectral evolution. The re- emergence of the power-law that dominated the pre-flare spectrum is evidence that NICER is catching the re-formation of the corona caught in real time following its disruption, which places much needed constraints on the timescale of the corona heating mechanism.

301.03 — The extreme velocities of the Ultra-fast Outflow components in the Quasar PDS 456

Rozenn Boissay Malaquin[1]; Ashkbiz Danehkar[2]; Herman Marshall[1]; Michael Nowak[1,3]

[1] *MKI, MIT (Cambridge, Massachusetts, United States)*

[2] *CfA (Cambridge, Massachusetts, United States)*

[3] *Washington University (Saint Louis, Missouri, United States)*

I will present the spectral analysis of *Chandra*/HETGS and *NuSTAR* observations of the quasar PDS 456 from 2015, and *XMM- Newton* and *NuSTAR* archival data from 2013-2014, together with *Chandra*/HETGS data from 2003. These *Chandra*/HETGS data, never analyzed before, represent a great value for studying UFOs in the low and medium X-ray energy bands, at high energy resolution. We analyzed the three different epochs in a consistent way, looking for absorption features corresponding to highly ionized blueshifted absorption lines from H-like and He-like ions of iron and nickel, as well as of other elements (O, Ne, Si, and S) in the soft band. We confirm the presence of a persistent ultra-fast outflow (UFO) with a velocity of v_{out} = –0.24-–0.29c, previously detected in several works. We also report the detection of an additional faster component of the UFO with a relativistic velocity of v_{out} = –0.48c. Such fast UFOs have already been found in some AGN at high redshift, but outflows with such a huge velocity have never been detected in AGN from the local Universe. We implemented photoionization modeling, using XSTAR analytic model warmabs, to characterize the physical properties of the different kinematic components of the ultra-fast outflow and of the partial covering absorber detected in PDS 456. These two relativistic components of the ultra-fast outflow observed in the three epochs analyzed here are powerful enough to impact the host galaxy of PDS 456 through AGN feedback.

301.04 — Weighing black holes with tidal disruption events

Brenna Mockler[1,2]

[1] *Department of Astronomy & Astrophysics, UC Santa Cruz (Santa Cruz, California, United States)*

[2] *DARK, Niels Bohr Institute, University of Copenhagen (Copenhagen, Denmark)*

While once rare, observations of tidal disruption events are quickly becoming commonplace. To continue to learn from these events it is necessary to robustly and systematically compare our growing number of observations with theory. Here I present a tidal disruption model (as part of the transient fitting code MOSFiT) and the results from fitting 14 TDEs. Our model uses hydrodynamical simulations to generate accretion rates and passes these accretion rates through viscosity and light reprocessing modules to create multi-wavelength light curves. It then uses an MCMC fitting routine to compare these theoretical light curves with observations. This procedure provides a robust method for measuring the masses of supermassive black holes because the shape of a TDE light curve depends strongly on the black hole's mass. In addition to describing this new black hole mass measurement method, I will discuss the implications these fits have for understanding the physics of TDEs, particularly for accretion under these extreme conditions.

301.05 — X-ray activity in Low Surface Brightness Galaxies

Edmund Hodges-Kluck[1,2]; Elena Gallo[3]

[1] *Department of Astronomy, University of Maryland (Greenbelt, Maryland, United States)*

[2] *NASA/GSFC (Greenbelt, Maryland, United States)*

[3] *University of Michigan (Ann Arbor, Michigan, United States)*

Low surface-brightness galaxies (LSBGs) make up half of the galaxies in the nearby Universe but remain almost entirely unexplored by X-ray observations. Motivated by the possibility that they are useful for measuring the local black hole occupation fraction to high precision, which requires thousands of galaxies, we observed 35 galaxies within 75 Mpc with Chandra. 15% of the galaxies have a nuclear X-ray source consistent with a massive black hole, although only one is a bona fide AGN. Most LSBGs in our sample have a large gas fraction, but we find that they are consistent with the X-ray luminosity–stellar mass correlation found in early-type galaxies and not with a correlation based on gas and stellar mass. LSBGs also have the expected number of luminous X-ray binaries for their (low) stellar masses. We thus conclude that LSBGs are useful targets for a wide-field, high resolution (Lynx or AXIS) X-ray survey of local, massive black holes and present a sketch of such a survey.

301.06 — Probing Blazar Emission Processes with Optical/γ-ray Flare Correlations

Ioannis Liodakis[1]; Roger Romani[1]; Daniel Kocevski[2]

[1] *Department of Physics, Stanford University, Kavli Institute for Particle Astrophysics and Cosmology (Stanford, California, United States)*

[2] *Marshall Space Flight Center (Huntsville, Alabama, United States)*

Even with several thousand Fermi-LAT blazar detections, the γ-ray jet emission mechanisms are poorly understood. Although popular models point towards leptonic processes, the recent possible neutrino association with a γ-ray flare challenges our understanding of these processes implicating a hadronic contribution to the high energy emission of blazar jets. We explored the temporal relation and correlated flux variations between optical and γ-rays for a large number of gamma-ray blazars regularly monitored by the KAIT, the SMARTS, and the Steward Observatory. By combining the temporal information with a Bayesian block light curve decomposition analysis, we explored the statistics of intraband and "orphan" flares. After accounting for sampling and observational sensitivity, we find that although leptonic processes appear to be dominant, there is still room for a small admixture of hadron generated events. Since leptonic processes appear to be mostly responsible for the γ-rays, we developed a method to statistically recover the emission mechanism (Synchrotron self-Compton, External Compton) in individual sources. While source classes show composite optical-to-γ-ray behavior, the majority of BL Lac objects favor a Synchrotron Self-Compton origin for the γ-rays. Flat Spectrum Radio Quasars favor External Compton emission.

302 — Dissertation Prize Talk: Searching for the Heaviest Elements with Multi-Messenger Astronomy, Jennifer Barnes (Columbia University)

302.01 — Searching for the Heaviest Elements with Multi-Messenger Astronomy

Jennifer Barnes[1]
[1] *Columbia University (New York, New York, United States)*

The merger of a neutron star with a second neutron star or a black hole produces a quasi-thermal transient powered by the radioactive decay of unstable nuclei assembled during the merger by rapid neutron capture (the r-process). This emission, called a kilonova, is a promising electromagnetic (EM) counterpart to the gravitational wave signals produced by such mergers. Observations of kilonovae allow the determination of the mass and composition of the material ejected by a merger, which is important for constraining the neutron star equation of state and understanding the astrophysical origin of r-process elements. However, interpreting observations requires robust models of kilonova emission, and the construction of such models is challenging due to the complexity of the r-process and the lack of relevant experimental data. I will present theoretical work that enabled the development of detailed and accurate kilonova models. I will discuss the optical properties of r-process material, and show how theoretically-derived synthetic r-process opacities changed our expectation of kilonova colors, provided a tool to differentiate light from heavy regimes of r-process nucleosynthesis, and facilitated the development of multi-component kilonova models. Next, I will show how modeling the transport of radioactive decay products in the kilonova ejecta improved predictions of kilonova light curves and established a connection between bolometric luminosity and the details of r-process radioactive decay. Finally, I will review the role of these models in the interpretation of the EM emission from the first detected neutron star merger, GW170817.

303 — Mission & Instruments II

303.01 — A Mission Status Update on the X-ray Imaging and Spectroscopy Mission (XRISM)

Brian J. Williams[1]*; Richard Kelley*[1]*; Robert Petre*[1]
[1] *X-ray Astrophysics Laboratory, NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

The X-Ray Imaging and Spectroscopy Mission (XRISM), an international collaboration led by JAXA and involving major participation from NASA and ESA, will employ an advanced X-ray observatory with capabilities to carry out a science program to address some of the important questions of present-day astrophysics. XRISM is essentially a rebuild of the the Hitomi (Astro-H) spacecraft that was lost due to an operational mishap early in the mission in 2016, but only employs two of the original four instruments on Hitomi. The Resolve Soft X-ray Spectrometer is being developed jointly by a team led by NASA/GSFC and institutions in Japan under the direction of JAXA's Institute of Space and Astronautical Science. It is a high-resolution, non-dispersive X-ray spectrometer operating between 0.3-12 keV. It is the core instrument on XRISM, providing a high-resolution spectroscopic capability ($\sim$ 5 eV) for the mission and covering the energy band where all of the astrophysically abundant elements have characteristic emission lines that can be used for a wide range of spectral studies of matter under extreme conditions. The other instrument, named Xtend and

provided by JAXA, extends the field of view to produce an observatory with extraordinary capabilities using a state of the art X-ray charged couple device camera. Xtend is the responsibility of JAXA, but NASA will provide an X-ray Mirror Assembly for the instrument identical in design to the Resolve mirror assembly. XRISM will be launched into low-Earth orbit (nominally 575 km circular, 31° inclination) from the Tanegashima Space Center, Japan, using a JAXA H-IIA rocket. This talk will summarize the status of the mission, and will outline the science objectives to be addressed, namely: 1) structure formation of the Universe and evolution of clusters of galaxies; 2) the life cycle of baryonic matter in the universe; 3) evolution and feedback from black holes; and 4) new science achieved through unprecedented high resolution X-ray spectroscopy.

303.02 — The Transient High Energy Sky and Early Universe Surveyor (THESEUS)

Lorenzo Amati[1]; P. O'Brien[2]; Diego Gotz[3]; Enrico Bozzo[4]
[1] *INAF - OAS Bologna (Bologna, BO, Italy)*
[2] *University of Leicester (Leicester, United Kingdom)*
[3] *CEA - IRFU (Paris, France)*
[4] *Univesity of Geneva (Geneve, Switzerland)*

The Transient High-Energy Sky and Early Universe Surveyor (THESEUS) is a space mission concept, developed by a large international collaboration and recently selected by ESA for a phase 0/A study within the Cosmic Vision - M5 selection process. THESEUS aims at exploiting Gamma-Ray Bursts for investigating the early Universe and at providing a substantial advancement of multi-messenger and time-domain astrophysics, also in strong sinergy with the large observing facilities of the future. These goals will be achieved through a unique combination of instruments allowing GRBs and X-ray transients detection over a broad FOV (more than 1sr) with 0.5-1 arcmin localization, an energy band extending from several MeVs down to 0.3 keV and high sensitivity to transient sources in the soft X-ray domain, as well as on-board prompt (few minutes) follow-up with a 0.7 m class IR telescope with both imaging and spectroscopic capabilities. THESEUS will address main open issues in cosmology such as, e.g., star formation rate and metallicity evolution of the inter- stellar and intra-galactic medium up to redshift 10-12, signatures of Pop III stars, sources and physics of re-ionization, and the faint end of the galaxy luminosity function. In addition, THESEUS will provide a fundamental contribution to time-domain and multi-messenger astrophysics by detecting, localizing, and identifying the electromagnetic counterparts to sources of gravitational radiation, which will be routinely detected in the late '20s / early '30s by next generation facilities like aLIGO/aVirgo, eLISA, KAGRA, and Einstein Telescope and, more in general, of several classes of transient sources, providing an ideal sinergy also with the large multi-wavelength observatories of the near future like LSST, ELT, TMT, SKA, CTA, ATHENA).

303.03 — Athena: ESA's mission to explore the Hot and Energetic Universe

Kirpal Nandra[1]
[1] *Max Planck Institute for Extraterrestrial Physics (Garching, Germany)*

Athena, the Advanced Telescope for High ENergy Astrophysics, is the X-ray observatory mission selected by ESA to address the Hot and Energetic Universe science theme. It is the second Large mission within ESA's Cosmic Vision program, and is due for launch in the early 2030s. Athena will reveal how hot baryons assemble into groups and clusters of galaxies, determine their chemical enrichment across cosmic time, measure their mechanical energy and characterise the missing baryons which are expected to reside in intergalactic filamentary structures. Athena will also find accreting supermassive black holes into the epoch of reionization, trace their growth even when in obscured environments, and show how they influence the evolution of galaxies and clusters through feedback processes. It will also have a fast target of opportunity observational capability, enabling studies of GRBs and other transient phenomena. As an observatory, Athena will offer vital information on high energy phenomena on all classes of astrophysical objects, from solar system bodies to the most distant objects known.

Athena will consist of a single large-aperture grazing incidence X-ray telecope with 12m focal length and 5 arcsec HEW angular resolution, utilizing the novel Silicon Pore Optics technology developed in Europe. The focal plane contains two instruments. One is the Wide Field Imager (WFI) providing sensitive wide field imaging and spectroscopy and high count rate capability. The other is the X-ray Integral Field Unit (X-IFU) delivering spatially resolved high high resolution X-ray spectroscopy. This presentation will focus on recent progress in the mission's development.

303.04 — Revealing the Invisible Universe with Lynx

Alexey Vikhlinin[1]; *Laura Lopez*[2]
[1] *Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*
[2] *Ohio State University (Columbus, Ohio, United States)*

The next-generation X-ray observatory Lynx will provide unprecedented X-ray vision into the otherwise invisible Universe with unique power to directly observe the dawn of supermassive black holes, reveal the drivers of galaxy formation, trace stellar activity including effects on planet habitability, and transform our knowledge of endpoints of stellar evolution. In this talk, I will describe how these science goals will be enabled by a mission design that combines lightweight X-ray mirrors with a high-definition X-ray imager with 0.5" pixels, a microcalorimeter with 0.3 eV energy resolution, and a large effective area grating spectrometer with a resolving power of 5000. Just as importantly, these features will facilitate a broadly capable observatory for the community that is able to tackle not only the known outstanding key science questions but whatever new problems are revealed in the coming decade.

304 — Accreting Black Holes: Recent Transients and Advances to Spectral Models

304.01 — NICER follow-up of the new black hole transient MAXI J1820+070

Erin Kara[1]
[1] *Department of Astronomy, University of Maryland / NASA GSFC (College Park, Maryland, United States)*

On March 11, 2018, a new black hole transient, MAXI J1820+070 emerged from quiescence to become one of the brightest sources in the X-ray sky. In this talk, I will give an overview of the subsequent X-ray observations as it transitioned from hard coronal-dominated to soft-thermal dominated, and back again. I will put particular emphasis on NICER observations that revealed reverberation lags that shortened by an order of magnitude during the luminous hard state, during which the shape of the broad iron line remained constant. This suggests that the state transition is driven by a change in the vertical extent of the corona, rather than a reduction in the truncation radius of the accretion disc.

304.02 — Timing Properties of New Black Hole Transients

Abigail Stevens[1,2]
[1] *Michigan State University (East Lansing, Michigan, United States)*
[2] *University of Michigan (Ann Arbor, Michigan, United States)*

The light curves of black hole X-ray binaries show variability on timescales from milliseconds to months. The shorter (sub-second) variability is particularly interesting because it probes the inner region of the accretion disk around compact object. Many exciting black hole transients have gone into outburst in the past year, and from them we have seen the timing signatures of broadband (or band-limited) noise and quasi-periodic oscillations (QPOs) in soft and hard X-ray bands. In this talk, I will discuss and compare timing observations of new transients such as MAXI J1535-571, Swift J1658.2-42, MAXI J1727-203, MAXI J1631-471, Swift J1728.9-3613, and MAXI J1348-630, and recent outbursts of known transients like GX 339-4 and 4U 1630-47.

304.03 — Spin Measurements of Black Holes in X-ray Binary Systems

James F. Steiner[1]
[1] *MIT Kavli Institute (Cambridge, Massachusetts, United States)*

One of the most remarkable properties of an astrophysical black hole is that it can be completely described by just its mass and spin. Knowledge of spin is important for testing models of black hole formation, relativistic jets, GRBs, and more. There are two primary spectral techniques by which spin is being measured: the "reflection" and "continuum-fitting" methods. In both cases, spin is obtained by measuring the inner radius of the accretion disk, which corresponds to the innermost stable circular orbit (ISCO). I will describe these techniques and present an overview of ongoing measurements of black hole spin in black-hole binary / transient systems.

304.04 — The nature of the X-ray corona in black hole binaries and AGN

Anne Lohfink[1,2]
[1] *Department of Physics, Montana State University (Bozeman, Montana, United States)*
[2] *eXtreme Gravity Institute (Bozeman, Montana, United States)*

Accreting black holes are powerful sources of radiation. The conversion of gravitational energy into radiation is thought to take place in an accretion disk/corona system just outside the black hole. In this system thermal, accretion disk photons are upscattered in a corona of hot electrons situated above the accretion disk producing X-rays. The nature of this Comptonizing corona remains a key open question in astrophysics. In my talk I will discuss new insights from recent observations of galactic black hole binary and AGN coronae.

304.05 — Advances and Challenges to Spectral Models for Accreting Black Holes

Javier A. García[1,2]
[1] *California Institute of Technology (Pasadena, California, United States)*
[2] *Dr Karl-Remeis Observatory (Bamberg, Germany)*

The intricate physical phenomena taking place in the vicinity of active black holes—either stellar-mass in binary systems undergoing an outburst, or supermassive black holes in the active centers of galaxies—manifest most prominently in the energetic bands of the electromagnetic spectrum (ultraviolet, X-rays, and Gamma rays). Observational spectral signatures can be various and complex, such as multicolor thermal emission (from the accretion disk); non-thermal continuum emission (produced by the mysterious corona), fluorescence emission lines, radiative recombination continua, and absorption edges (due to reflection in the disk); plus warm and hot absorption from dense material in the line of sight (disk winds, ultra-fast outflows). Moreover, these features are susceptible to relativistic effects (dropper and gravitational shifts, relativistic boosting) if produced within the reach of the black hole's gravitational field. Thus, spectral models are expected to accurately reproduce all these components, and their interplay, in order to access fundamental quantities that describe these systems. This talk presents a short overview of the recent advances in theoretical models for the interpretation of these observable phenomena, with emphasis in relativistic X-ray reflection models. We describe the complexity of current models in the pursuit of physical consistency, driven by the constant increase of higher quality observational data, and discuss their performance in providing accurate estimates on black hole spins, geometry and evolution of the corona and disk, and in the properties of the accreting material. We will show some of the most important challenges confronted by these theoretical efforts, and our plans and expectations for future advances.

305 — Extremely Normal: Very High Energy Emission from Near-Main Sequence Stars

305.01 — Non-Thermal High Energy Emission from the Massive Colliding Wind Binary Systems

Kenji Hamaguchi[1,2]; *Michael Corcoran*[1,3]
[1] *NASA's GSFC (Greenbelt, Maryland, United States)*
[2] *UMBC (Baltimore, Maryland, United States)*
[3] *The Catholic University of America (Washington DC, District of Columbia, United States)*

The collision of strong stellar winds in massive binary systems creates powerful shocks, which accelerates a small amount of particles to relativistic energies at the shock interface. This process is important in fundamental astrophysics in two ways; i) some particles may contribute to cosmic-rays observed around the Earth, whose origin is not well known, and ii) it provides a good laboratory for particle acceleration physics as the shock occurs steadily in a predictable environment. Some relativistic particles collide with stellar photons or ambient material near the binary system and emit non- thermal X-rays and/or γ-rays, which are good probes of particle acceleration. This emission had been searched for decades but not found convincingly without sensitive high-energy telescopes.

The *NuSTAR* telescope observed the enigmatic supermassive binary system η Carinae multiple times after 2014 and found conclusive evidence of non-thermal emission from the star in the extremely hard X-ray band. This emission is prominent between 20-50 keV, below which thermal emission from shock colliding plasma dominates. It is relatively stable throughout the binary orbit, but it disappears near periastron when the wind colliding activity shuts off. This variation indicates that the non- thermal X-ray emission originates from the head-on wind-wind collision. The flat spectrum is consistent with inverse-Compton of stellar UV photons by accelerated electrons. The spectrum smoothly connects to a gamma-ray spectrum of a Fermi source detected around η Carinae, suggesting that acceleration occurs up to the GeV energy.

This result provides the strongest evidence so far that particle acceleration occurs at the wind colliding shock of a massive colliding wind binary system. *NuSTAR* also found a similar extremely hard X-ray emission from the prototypical massive colliding wind binary system WR140, while it did not from the nearby massive binary system, γ^2 Velorum, which may be detected in γ-rays with Fermi. We introduce

these observing results with *NuSTAR* and discuss the condition of particle acceleration at the wind-wind colliding shocks.

305.02 — New Star Observations with *NuSTAR*: Flares from Young Stellar Objects in the ρ Ophiuchi Cloud Complex in Hard X-rays

Juliana Vievering[1]; Lindsay Glesener[1]; Brian Grefenstette[3]; David Smith[2]

[1] *University of Minnesota (Minneapolis, Minnesota, United States)*

[2] *University of California (Santa Cruz, California, United States)*

[3] *California Institute of Technology (Pasadena, California, United States)*

Young stellar objects (YSOs), which tend to flare more frequently and at higher temperatures than what is typically observed on Sun-like stars, are excellent targets for studying the physical processes behind extreme flaring events. In the hard X-ray regime, radiation can penetrate through dense circumstellar material, and it is possible to measure thermal emission from hot plasma and to search for nonthermal emission from accelerated particles, which are key components for understanding the nature of energy release in these flares. To investigate hard X-ray emission from YSOs, three 50ks observations of a star-forming region called ρ Ophiuchi have been taken with the *Nuclear Spectroscopic Telescope Array* (*NuSTAR*). Through use of direct focusing optics, *NuSTAR* provides unprecedented sensitivity in the hard X-ray regime above 10 keV, making these YSO observations the first of their kind. Multiple stellar flares have been identified in the data set; here we present spectral and timing analyses of the brightest of the these events, exploring the way energy is released as well as the effects of these large flares on the surrounding environment.

305.03 — Some Like it (Very) Hot: The Hot Side of Cool Stars

Rachel Osten[1,2]

[1] *Space Telescope Science Institute (Baltimore, Maryland, United States)*

[2] *Johns Hopkins University (Baltimore, Maryland, United States)*

That normal stars in the cool half of the HR diagram can heat plasma in their outer atmospheres to million degree temperatures as the result of magnetic reconnection is well known. This is based both on detailed studies of our nearby star, the Sun, as well as decades of study by high energy astronomy satellites. The understanding of stellar outer atmospheres by reference to scaling laws established for the Sun forms the underpinning of the solar- stellar connection. Stellar extemes of magnetic activity reveal themselves in the total integrated flare energies, the peak flare flux, as well as peak flare temperatures. There is a well-known scaling relation between peak flare temperatures and volume emission measures, found to hold for both solar flares and a heterogeneous collection of stellar flares from earlier X-ray missions. I will present recent results showing the extremes of temperature exhibited in stellar flares, regimes very unlike what is seen in solar flares. I will discuss the evidence for temperatures in excess of 100 million degrees on normal stars, and the circumstances under which these are found. These results hint at a departure from the scaling relation for lower temperature solar and stellar flares. I will highlight some possible interpretations for this in light of the "HR diagram of magnetic reconnection".

305.04 — High Energy Emission Processes from Normal Stars and Stellar Clusters

Ian Stevens[1]

[1] *School of Physics and Astronomy, University of Birmingham (Birmingham, West Midlands, United Kingdom)*

In this talk I will review the emission processes that can generate high energy emission from normal stars, with a focus on stars that have been observed with FERMI and NUSTAR, as well as ground-based Cerenkov telescopes (HESS, VERITAS, MAGIC).

I will discuss colliding stellar winds and other relevant interactions in primarily massive stars (shocks/B-fields etc), and then discuss the various processes that contribute to (or indeed inhibit) high energy emission from such stars. The connection with other wavelengths (notably non-thermal radio emission) will also be discussed.

I will extend this discussion to include emission from very young and massive stellar clusters (eg Westerlund 2) and potential emission from bowshocks around runaway stars, as well as touching on high energy emission from lower mass stars.

305.05 — Acceleration Potential of a Cygnus Star Forming Region with HAWC data

Binita Hona[1]

[1] *Department of Physics, Michigan Technological University (Houghton, Michigan, United States)*

The Fermi-LAT detected an extended gamma-ray emission located in the star forming (SFR) region of Cygnus X and attributed to a possible superbubble with freshly accelerated cosmic rays (CRs). The emission region is surrounded by ionization fronts as in a cocoon. Hence, it has been named the ”Cygnus cocoon”. One theory behind the origin of CRs in the cocoon is that they originate in the OB2 association and are accelerated at the interaction sites of stellar winds of massive O type stars. This supports the hypothesis of SFRs as possible sources of cosmic rays in our galaxy. So far, this cocoon has been only detected at GeV energies. A TeV gamma-ray source 2HWC J2031+415, detected by the HAWC observatory is colocated with the cocoon. Spectral and morphological studies of the region with HAWC and Fermi-LAT data reveal the HAWC source as a likely counterpart of the cocoon. Using HAWC data, we are able to probe the maximum energy to which cosmic rays are accelerated in the Cygnus OB2 SFR.

400 — Galaxy Clusters

400.01 — Probing AGN-Inflated Cavities in Galaxy Cluster MS 0735+74 with the Sunyaev-Zel'dovich Effect

Adam Mantz[1]; Zubair Abdulla[2]; John Carlstrom[2]; Daniel Marrone[3]; Christine O'Donnell[3]

[1] *Stanford University (Stanford, California, United States)*
[2] *University of Chicago (Chicago, Illinois, United States)*
[3] *University of Arizona (Tucson, Arizona, United States)*

We report the first detection of the Sunyaev-Zel'dovich (SZ) signature of cavities in the intracluster medium (ICM) associated with radio-mechanical feedback from an active galactic nucleus (AGN) in the center of a galaxy cluster. Such cavities are seen as regions of reduced brightness in X-ray images; while this reduction in brightness requires a significant local reduction in ICM density, X-ray data alone cannot easily constrain the temperature or nature of the material within the cavities. However, measurements of the SZ effect from these structures can begin to shed light on their contents, when combined with X-ray constraints on the pressure of the surrounding gas. We have mapped galaxy cluster MS 0735+74, which hosts the most powerful AGN outburst known, at 30 GHz using the Combined Array for Research in Millimeter-wave Astronomy (CARMA). We find a clear reduction of the SZ signal in the direction of the cavities within the cluster, corresponding to a deficit of ambient-temperature plasma, as indicated by the X-ray data. Thermal support of the cavities by gas with a temperature of less than several hundred keV can be ruled out, while cosmic rays or magnetic fields providing nonthermal support are still viable options.

400.02 — Intra-cluster X-ray Source Populations in Virgo and Fornax

Zhiyuan Li[1]

[1] *Department of Astronomy, Nanjing University (Nanjing, China)*

X-ray-emitting, close binary systems are among the first objects discovered in the X-ray sky and now understood to be ubiquitous in the Universe. As such, X-ray binaries can serve as a useful tool to study the evolution of their parent stellar populations, on scales from star clusters to galaxy clusters. We report observational evidence for the presence of intracluster X-ray sources in the two nearest galaxy clusters, Virgo and Fornax, based primarily on archival Chandra observations. We discuss the origin of these sources, in terms of supernova-kicked low-mass X-ray binaries (LMXBs), LMXBs in globular clusters, LMXBs associated with the diffuse intra-cluster light, tidally- stripped nucleated dwarf galaxies and free-floating massive black holes. The discovery of intracluster X-ray sources opens a new avenue for studying the structural growth in galaxy clusters.

400.03 — Heating and Acceleration at Galaxy Cluster Shocks: Insights from *NuSTAR*

Daniel R. Wik[1]

[1] *Department of Physics & Astronomy, University of Utah (Salt Lake City, Utah, United States)*

Mergers between galaxy clusters drive weak shock fronts into the intracluster medium, capable of both heating the gas and accelerating relativistic particles. Measurements of the high temperature gas and non-thermal inverse Compton (IC) emission that result from these shocks most benefit from sensitive observations at hard X-ray energies. *NuSTAR* observations of the Bullet cluster, Abell 2163, Abell 665, and most recently, Abell 2146—all massive merging clusters—lead to improved measurements of both the thermal and IC components in these clusters. *NuSTAR* temperature constraints at shock fronts are used to test competing models of electron heating, namely whether electrons are heated directly by the shock or if they reach the shock temperature further behind the front through interactions with ions. In order to resolve the small angular scales necessary to distinguish these models, we apply a joint *Chandra-NuSTAR* forward-fitting approach to image data, allowing *Chandra* to determine the density distribution of the gas while *NuSTAR* constrains its temperature. Interestingly, we measure temperatures in between the predictions of the two models for the Mach 3 shocks in the Bullet cluster and Abell 665, in contrast with temperature constraints from *Chandra* data alone. We also preview recent *NuSTAR* observations of Abell 2146 and its two shock fronts and present constraints on the flux of IC emission from the electrons producing radio halos in all four clusters.

400.04 — Exploring the missing baryons using absorption studies

Akos Bogdan[1]; Orsolya Kovacs[1]; Randall Smith[1]; Ralph Kraft[1]; William R. Forman[1]

[1] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*

In the low-redshift (z < 2) universe, about one-third of the baryons remain unaccounted for, which poses the long-standing missing baryon problem. The missing baryons are believed to reside in filaments connecting galaxies in the form of warm-hot intergalactic medium (WHIM). Although UV absorption studies explored the warm phase of the WHIM, it is hypothesized that notable fraction of the missing baryons is in the hot X-ray phase. However, X-ray spectroscopy is limited by the low effective area of currently available instrumentation, thus the conclusive observational evidence is still lacking. In this work, we used a novel approach and utilized Chandra LETG spectra of a luminous AGN, along with previous redshift measurements of UV absorption line systems, and applied a stacking method to gain unparalleled sensitivity. Based on the stacked data, we detect an OVII absorption line that exhibits a Gaussian line profile and is statistically significant at the 3.3 sigma level. Since the redshifts of the UV absorption line systems were known a priori, this is the first definitive detection of an X-ray absorption line originating from the WHIM. Based on this detection we constrain the contribution of the WHIM to the overall baryon budget.

400.05 — When Galaxy Clusters Collide: Shocking tales of structure formation

Andra Stroe[1]

[1] *Center for Astrophysics | Harvard & Smithsonian (Cambridge, Massachusetts, United States)*

Red weather alert: dangerous cosmic weather forecast, in light of galaxy cluster mergers! Clusters grow through mergers with other clusters, events which give rise to the largest cosmic shock waves. Shocks travel like giant tsunamis through the electron plasma and shape the evolution of the intracluster medium. Giant radio relics trace these shock fronts and are thought to form when accelerated electrons emit synchrotron radiation in the presence of a magnetic field. I will present results from the widest frequency study of radio relics, where we combine, for the first time, data covering more than 2 order of magnitude in radio frequency. Our very low and very high radio frequency data challenge the simple, widely accepted model for relic formation. Using unique observations spanning the 150 MHz to 30 GHz range, I will derive physical parameters, such as Mach numbers and electron ages, as well as constrain injection mechanisms. I will also discuss how new models involving re-acceleration of aged seed electrons or evolving magnetic fields can alleviate the discrepancies between observations of relics and theory.

400.06 — Constraining merger geometry of galaxy clusters with multi-wavelength observations and hydrodynamical simulations: The case of Abell 2146

Urmila Chadayammuri[1,2]; John ZuHone[1]; Paul Nulsen[1]; Daisuke Nagai[2]

[1] *High Energy Astrophysics Division, Chanda X-Ray Center (Somerville, Massachusetts, United States)*

[2] *Yale University (New Haven, Connecticut, United States)*

Merging galaxy clusters provide unique constraints on the nature of dark matter and the plasma physics of X-ray emitting intracluster medium (ICM). Offsets between the collisionless stars, dissipative gas, and lensing mass in merging systems like the Bullet Cluster provide constraints on the self- interaction cross-section of the dark matter. Properties of shock and cold fronts yield unique constrains on the microphysics of the ICM, such as the efficiency of electron-proton (e-p) equilibration, conductivity, and viscosity. However, given the complex structure of merging clusters, hydrodynamical simulations matching their geometry and dynamics are vital to meaningfully extract physical properties of dark matter and ICM plasma physics from observations. In this work, we present a novel method to constrain parameters of merging galaxy clusters, including the masses, impact parameter and relative velocities of two merging galaxy clusters, by using X-ray emissivity and temperature and lensing maps as well as automated detection of shock and cold fronts and Mach number across them. We test this method by analyzing mock X-ray and lensing observations of a suite of idealized galaxy cluster merger simulations performed using the GPU-accelerated adaptive mesh refinement code GAMER-2. We will also discuss the application of this method to the Chandra-VLP observations of the merging Bullet-like cluster Abell 2146.

401 — Stellar Compact II

401.01 — On the MADness of Black Hole-Accretion Disk Systems in Gamma-ray Bursts.

Nicole Lloyd-Ronning[1]
[1] *Los Alamos National Lab & UNM, LA (Los Alamos, New Mexico, United States)*

The conditions required to launch powerful, relativistic jets from black hole-accretion disk systems are not fully understood. The Blandford-Znajek mechanism is one robust way to launch such a jet. However, this process can require a large amount of magnetic flux near the black hole horizon which can lead to a magnetically arrested disk (MAD) around the black hole central engine. We show that the observed gamma-ray burst luminosities for long and short gamma-ray bursts suggest magnetic fluxes that lead to a MAD state in the disk. This state can, in turn, naturally explain a number of properties in the observed prompt gamma-ray GRB light curve, including the average variability timescale and the correlation between variability timescale with Lorentz factor and GRB luminosity.

401.02 — Measuring the Spin and Inclination of the Black Hole Transient MAXI 1820+070 using NICER and NuSTAR spectra

Andrew Fabian[1]*; Douglas Buisson*[1]
[1] *Institute of Astronomy, University of Cambridge (Cambridge, United Kingdom)*

The bright X-ray transient MAXI1820+0870 was observed many times with NICER and NuSTAR during its outburst in 2018. We present the results of joint fits to the X-ray spectra made in both hard and soft states and the transitions between them, using high density REFLIONX and KERRBB models where relevant. Best-fit values of spin, inclination and coronal properties will be discussed.

401.03 — NICER monitoring of the Big Glitcher PSR J0537-6910

Wynn C.G. Ho[1]*; Zaven Arzoumanian*[4]*; Slavko Bogdanov*[2]*; Teruaki Enoto*[3]*; Paul S. Ray*[5]
[1] *Department of Physics and Astronomy, Haverford College (Haverford, Pennsylvania, United States)*
[2] *Columbia University (New York, New York, United States)*
[3] *Kyoto University (Kyoto, Japan)*
[4] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[5] *US Naval Research Laboratory (Washington, District of Columbia, United States)*

Pulsars are famous for having very precisely measured spin rates, and this rate evolves extremely regularly for most pulsars. However, the spin rate of young pulsars can occasionally undergo sudden changes, known as glitches. PSR J0537-6910 is unique among all known pulsars in the number of glitches it underwent (45 in 13 years of RXTE observations) and the observed predictability of when its glitches take place. We report on timing analyses of ongoing NICER observations of PSR J0537-6910. The resulting timing model determined using NICER is crucial for LIGO/Virgo searches of gravitational waves from this pulsar, whose spin behavior could be due in part to gravitational wave emission.

NICER is a 0.2-12 keV X-ray telescope operating on the International Space Station. The NICER mission and portions of the NICER science team activities are funded by NASA.

401.04 — On the Nature of the X-Ray Emission from the Ultraluminous X-Ray Source, M33 X-8: New Constraints from *NuSTAR* and *XMM-Newton*

Lacey West[1]*; Bret Lehmer*[1]*; Daniel Wik*[2]*; Jun Yang*[2]*; Dom Walton*[3]*; Vallia Antoniou*[4,5]*; Frank Haberl*[6]*; Ann Hornschemeier*[7]*; Thomas Maccarone*[4]*; Paul Plucinsky*[5]*; Andrew Ptak*[7]*; Benjamin Williams*[8]*; Neven Vulic*[7,9]*; Mihoko Yukita*[7,10]*; Andreas Zezas*[5,11]
[1] *University of Arkansas (Fayetteville, Arkansas, United States)*
[2] *The Johns Hopkins University (Baltimore, Maryland, United States)*
[3] *Foundation for Research and Technology-Hellas (Heraklion, Crete, Greece)*
[4] *University of Utah (Salt Lake City, Utah, United States)*
[5] *University of Cambridge (Cambridge, United Kingdom)*
[6] *Texas Tech University (Lubbock, Texas, United States)*
[7] *Harvard-Smithsonian Center for Astrophysics (Cambridge, Massachusetts, United States)*
[8] *Max-Planck-Institut für extraterrestrische Physik (Garching, Germany)*
[9] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*
[10] *University of Washington (Seattle, Washington, United States)*
[11] *University of Maryland (College Park, Maryland, United States)*

Until recently, ultraluminous X-ray sources (ULXs) were almost all thought to contain black holes as their compact-object components. Recent detections of pulsations, along with ambiguities in modeling of broadband (0.3-30 keV) ULX spectra, however, have demonstrated a prevalence of neutron star compact objects among the general ULX population. The levels at which neutron star versus black hole compact object components exist within the ULX populations is a subject of current debate. The relatively nearby

(832 kpc) ULX M33 X-8 has a compact object whose nature has yet to be constrained and a 0.3–10 keV luminosity near the boundary of the "ultraluminous" classification, making it an important source for understanding the link between typical Galactic X-ray binaries and ULXs. Using newly obtained, nearly simultaneous NuSTAR and XMM- Newton observations of M33 X-8, we will present important new spectral constraints for this source. We further analyze XMM-Newton data taken over the last 17 years to show that small variations in the flux of M33 X-8 correlate with changes similar to those observed in other ULXs. The two most likely phenomenological scenarios suggested by the data are degenerate in terms of constraining the nature of the accreting compact object (i.e., black hole versus neutron star). However, we predict that future observations designed to observe M33 X-8 at different flux levels across the full 0.3–30 keV range would significantly improve our constraints on the nature of this important source.

401.05 — High energy excess and polarization in X-ray binaries using INTEGRAL

Victoria Grinberg[1]; Floriane Cangemi[2]; Tobias Beuchert[3]; thomas siegert[8,9]; Jerome Rodriguez[2]; Ingo Kreykenbohm[4]; Joern Wilms[4]; Katja Pottschmidt[5,6]; Philippe Laurent[7]

[1] *Institute for Astronomy and Astrophysics (IAAT)), Universitaet Tuebingen (Tuebingen, Germany)*

[2] *CEA Saclay / Lab AIM (Gif-sur-Yvette, France)*

[3] *UvA (Amsterdam, Netherlands)*

[4] *Remeis Observatory & ECAP (Bamberg, Germany)*

[5] *NASA GSFC (Greenbelt, Maryland, United States)*

[6] *UMBC (Greenbelt, Maryland, United States)*

[7] *CEA Saclay / Lab APC (Paris, France)*

[8] *MPE (Garching, Germany)*

[9] *UCSD (San Diego, California, United States)*

With upcoming missions such as IXPE and eXTP, we are standing on the very verge of the age of X-ray polarimetry. However, none of these future mission will cover the energies above 400 keV. Especially for X-ray binaries, measurements at such high energies are crucial: this is where we see an excess emission, the so-called "hard tail". Detection of polarization and its variability can constrain the origin of this excess emission. It can, in particular, answer the question whether this is the high-energy contribution of the jets that we see in the radio in the low/hard emission states. Luckily, for exceptionally bright sources and/or long exposures, polarization measurements in the very hard X-ray/soft gamma-ray band are possible already today with INTEGRAL.

Previously, we have utilized the Compton mode of the IBIS telescope onboard INTEGRAL to show that the hard tail in the black hole high mass X-ray binary Cygnus X-1 is highly polarized, a result that has been later independently confirmed by others using the INTEGRAL/SPI telescope. First measurements of state-resolved polarization confirmed a hard tail component and a high polarization fraction above 400 keV in the hard state, i.e., when we observe radio jets. In the soft state, when the radio emission from jets is either absent or strongly suppressed, the analysis was hampered by a lack of INTEGRAL observations. Here, we present an updated re-analysis of all INTEGRAL observation to date, including 6 years of new observations. We detect a hard tail component in both, hard and soft, states using IBIS and SPI and discuss implications of this result.

401.06 — Results from the Observations of the Accreting X-Ray Pulsar GX 301-2 with the X-Calibur Hard X-ray Polarimetry Mission

Henric Krawczynski[1]; Quin Abarr[1]; Richard Bose[1]; Dana Braun[1]; Gianluigi De Geronimo[2]; Paul Dowkontt[1]; Manel Errando[1]; Thomas Gadson[3]; Victor Guarino[4]; Scott Heatwole[3]; Nirmal Iyer[5]; Fabian Kislat[10]; Mózsi Kiss[5]; Takao Kitaguchi[6]; Rakhee Kushwah[5]; James Lanzi[3]; Shaorui Li[7]; Lindsey Lisalda[1]; Takashi Okajima[8]; Mark Pearce[5]; Zachary Peterson[3]; Brian Rauch[1]; David Stuchlik[3]; Hiromitsu Takahashi[9]; Jason Tang[1]; Nagomi Uchida[9]; Andrew West[1]; Keith Gendreau[8]; Peter A. Jenke[11]; Amy Y. Lien[12]; Jon Miller[13]; Hans Krimm[14]

[1] *Washington University in Saint Louis, Physics Dept., MCSS, CQS (Saint Louis, Missouri, United States)*

[2] *University of New Hampshire (Durham, New Hampshire, United States)*

[3] *University of Alabama (Huntsville, Alabama, United States)*

[4] *University of Maryland, CRESST, GSFC (Greenbelt, Maryland, United States)*

[5] *University of Michigan (Ann Arbor, Michigan, United States)*

[6] *USRA, CRESST, NSF, GSFC (Greenbelt, Maryland, United States)*

[7] *Stony Brook (New York, New York, United States)*

[8] *Wallops Flight Facility (Wallops Island, Virginia, United States)*

[9] *Guarino Engineering (Chicago, Illinois, United States)*

[10] *KTH, OKC (Stockholm, Sweden)*

[11] *RIKEN (Tokyo, Japan)*

[12] *Brookhaven National Laboratory (Upton, New York, United States)*

[13] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

[14] *Hiroshima University (Hiroshima, Japan)*

NASA's hard X-ray polarimetry mission X-Calibur was flown on a relatively short stratospheric balloon flight from McMurdo (Antarctic) from Dec. 29, 2018 to Jan. 1, 2019. The X-Calibur observations focused on the two accreting X-ray pulsars GX 301-2 and Vela X-1. X-Calibur observed GX 301-2 close to apastron in a rare flaring state with elevated flux levels. We report here for the first time on the results of the X-Calibur observations including the 15-60 keV light curve, the hard X-ray energy spectrum, the results from the phase resolved analysis, and the X-Calibur constraints on the linear polarization of the hard X-ray emission. We furthermore present results from simultaneous observations with X-Calibur, and the Neil Gehrels Swift and NICER X-ray telescopes. We conclude with a discussion of the neutron star, accretion physics, and fundamental physics constraints that can be obtained with future deeper polarimetric observations of accreting X-ray pulsars.

402 — Mid-Career Prize Talk: Cosmic Alchemy in the Era of Gravitational Wave Astronomy, Enrico Ramirez-Ruiz (UC Santa Cruz)

402.01 — Cosmic alchemy in the era of gravitational wave astronomy

Enrico Ramirez-Ruiz[1]
[1] *University of California, Santa Cruz (Santa Cruz, California, United States)*

The source of about half of the heaviest elements in the Universe has been a mystery for a long time. Although the general picture of element formation is well understood, many questions about the nuclear physics processes and particularly the astrophysical details remain to be answered. Here I focus on recent advances in our understanding of the origin of the heaviest and rarest elements in the Universe.

403 — A Revolution in the Studies of Classical Novae

403.01 — The AAVSO as a resource for transient science

Stella Kafka[1]
[1] *AAVSO (Cambridge, Massachusetts, United States)*

The American Association of Variable Star Observers was formed in 1911 as a group of US-based amateur observers obtaining data in support of professional astronomy projects. Now, it has evolved into an International Association with members and observers from both the professional and non-professional astronomical community, contributing photometry to a public photometric database of more than 25,000 variable objects, and using it for research projects. As such, the AAVSO's main claim to fame is that it successfully engages backyard Astronomers, educators, students and professional astronomers in astronomical research. I will present the main aspects of the association and how it has evolved with time to become a premium resource for variable star researchers. I will also discuss the various means that the AAVSO is using to support cutting-edge nova science, and how it engages its observers in projects building a stronger international astronomical community.

403.02 — Novae as Gamma-ray sources from radioactivities and particle acceleration

Margarita Hernanz[1]
[1] *Institute of Space Sciences (ICE), CSIC and IEEC (Bellaterra (Barcelona), Spain)*

Nova explosions synthesise radioactive nuclei, which are emitters of gamma- rays in the MeV range. Lines at 478 and 1275 keV correspond to ^{7}Be and ^{22}Na decays. In addition, positron-electron annihilation also produces gamma-ray emission, with the 511 keV line and a continuum below it. Gamma-ray spectra and light curves are unique tools to trace the corresponding isotopes and to give insights on the properties of the expanding envelope. Photons in the MeV energy range from nova explosions have not been detected yet, because past and current instruments (e.g., CGRO/Comptel and INTEGRAL/SPI) are not sensitive enough, and only novae closer than about 1 kpc are expected to be detected; there have not been candidates so far.

Another type of gamma-ray emission from novae originates in particle acceleration in strong shocks related to mass ejection. Shocks can be either external - between the nova ejecta and the dense wind of the red giant companion in symbiotic recurrent novae - or internal - within the nova ejecta of classical novae. Collisions between accelerated protons produce neutral pions which decay emitting photons with energies larger than 100 MeV (hadronic process); relativistic electrons are responsible for Inverse Compton emission, also at high energies (leptonic process). Fermi/LAT has detected high-energy gamma-rays in several novae, of both types, since its launch in 2008.

A review and update of both topics will be presented, together with the implications for the understanding of nova nucleosynthesis (MeV gamma-rays) and shocks during mass ejection (GeV gamma-rays).

403.03 — Neil Gehrels Swift Observatory studies of novae in outburst.

Kim Page[1]

[1] *Department of Physics & Astronomy, University of Leicester (Leicester, United Kingdom)*

The Neil Gehrels Swift Observatory, launched in 2004, was designed as a Gamma-Ray Burst chasing mission. While still regularly detecting and following up GRBs, the rapid response capabilities and daily planning of its observing schedule also make Swift an excellent instrument for observing other transient objects, including novae in the X-ray and UV bands. Swift has followed in detail the evolution of a number of both classical and recurrent novae, and here we report results highlights from these observations, including the high- amplitude flux variation often seen at the start of the super-soft emission, the differing relationships between the X-ray and UV variability, and the spectral evolution seen in the X-ray band.

403.04 — Nuclear burning as seen through the window of high resolution X-ray spectroscopy

Marina Orio[1,2]

[1] *University of Wisconsin, Dept. of Astronomy (Madison, Wisconsin, United States)*

[2] *INAF-Padova (Padova, Italy)*

19 novae in outburst and 8 non-nova supersoft X-ray sources have been observed with high resolution with the X-ray gratings aboard Chandra and XMM-Newton. In the case of novae, often the exposures have been repeated as the outburst evolved. This small library of interesting, often surprising spectra, is starting to show common characteristics and some puzzles we need to solve. Not all spectral lines have been identified yet, the supersoft X-ray sources are often partially covered or "obscured", there is periodic and aperiodic variabiity over several scales, in novae the absorption lines are blue-shifted by even over 2000 km/s (even if the models that predicted the observed spectrum indicate that the absoption features originate in an already static atmosphere)...these and other puzzles will be addresses in my talk. I will propose possible solutiosn for some of them. These observations allow us to explore new physics and to better understand binary evolution.

403.05 — Classical novae as lithium factories in the Galaxy

Luca Izzo[1]*; Paolo Molaro*[3]*; Massimo Della Valle*[4]*; Piercarlo Bonifacio*[2]

[1] *IAA-CSIC (Granada, Spain)*

[2] *Observatoire Paris (Paris, France)*

[3] *INAF-Trieste (Trieste, Italy)*

[4] *INAF-Napoli (Naples, Italy)*

The abundance of lithium observed in very young stellar populations is ∼4 times larger than the primordial one estimated by recent Planck measurements. Since Lithium is easily destroyed in stellar interiors, the search for astrophysical sources responsible for of the observed lithium over-abundance was a mystery for decades. In this talk I will present the results of an on- going survey dedicated to the study of nova outburst with high-resolution spectrographs at ESO/VLT. In particular, I will concentrate on the recent detection of beryllium-7 in the spectra of recent classical novae. While this finding is a further confirmation of the occurrence of the thermo-nuclear runaway in nova explosions, at same time it implies that classical novae are the main factories of lithium in the Galaxy.

403.06 — Novae after the gamma-ray emission phase: X-ray studies of the continuing evolution of shocks in V959 Mon

Koji Mukai[9,10]*; Thomas J. Nelson*[1]*; Laura Chomiuk*[2]*; JL Sokoloski*[3,4]*; Justin Linford*[5]*; Thomas Finzell*[2]*; Amy Mioduszewski*[6]*; Michael Rupen*[7]*; Jeniffer Weston*[8]

[1] *University of Pittsburgh (Pittsburgh, Pennsylvania, United States)*

[2] *University of Maryland, Baltimore County (Baltimore, Maryland, United States)*

[3] *Michigan State University (East Lansing, Michigan, United States)*

[4] *Columbia University (New York, New York, United States)*

[5] *LSST Corporation (Tucson, Arizona, United States)*

[6] *West Virginia University (Morgantown, West Virginia, United States)*

[7] *NRAO (Socorro, New Mexico, United States)*

[8] *Dominion Radio Astrophysical Observatory (Penticton, British Columbia, Canada)*

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

[10] *NASA Goddard Space Flight Center (Greenbelt, Maryland, United States)*

More than a dozen novae have been detected as GeV gamma-ray sources for several weeks around the time of visible light maximum. This requires particle acceleration in powerful shocks, whose thermal particles are expected to emit X-rays. Indeed, X-rays from such shocks are observed in many novae, usually weeks or months after the optical peak, and suggests a universal picture in which initial, slow ejecta collide with later, faster, outflows. Here we present Neil Gehrels Swift, Suzaku, and Chandra data on V959 Mon (Nova Mon 2012), which was discovered first as a transient Fermi/LAT source in 2012 June, while the object was too close to the Sun for optical or X-ray observations. The optical nova was discovered about two month later, when X-ray observations started. Our data are among the most comprehensive monitoring of X-rays from novae, along with those on V392 Vel (Nova Vel 1999). In V959 Mon, we observe a clear trend of decreasing N_H with time, which we model as due to the expansion of the unshocked slow ejecta ahead of the shock. Our analysis suggests that the slow ejecta did not start its secular expansion until about 30 days after the initial detection of the gamma-rays. The temperature and the emission measure of the X-ray emitting gas evolve in more subtle ways, roughly in line with what we expect in this complex situation involving the continuous addition of freshly shocked matter and relatively inefficient cooling of shocked gas. We suggest that both reverse and forward shock contributed to the observed Chandra grating spectra of V959 Mon. Finally, we discuss the implications for our understanding of the shock in the earliest days of the nova, during its gamma-ray emission phase.