16th HEAD Meeting
Sun Valley, Idaho – August, 2017
Meeting Abstracts

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99 – Public Talk - Revealing the Hidden, High Energy Sun, Rachel Osten

99.01 – Revealing the Hidden, High Energy Sun

Eclipses of the Sun happen when the Moon blocks the Sun's light from our view. It may seem puzzling, then, that solar physicists flock to study the Sun during these special events. Shouldn't there be nothing to see? Yet there is. I will talk about what the tantalizing solar features revealed during solar eclipses tell us about the Sun and its structure, as well as how this relates to what high energy solar satellites routinely discover without the need for eclipses. I will then make a leap into the cosmos to relate this to what astronomers are learning about the nearest stars and their abilities to make good homes for other planets.

Author(s): Rachel A. Osten[1]
Institution(s): *1. Space Telescope Science Institute*

100 – Solar/Stellar Compact I

100.01 – Observable Impacts of Exoplanets on Stars hosts – an X-ray perspective

Since soon after the discovery of hot Jupiters, it had been suspected that interaction of these massive bodies with their host stars could give rise to observable signals. We discuss the observational evidence for star-planet interactions (SPI) of tidal and magnetic origin observed in X-rays and FUV. While not all Hot Jupiters effect their hosts, in extreme cases they significantly impact the activity of their host stars through both tidal and magnetic interaction. This can lead to either increased or decreased stellar activity - depending on the internal structure of the host star and the properties of the hosted planet. In HD 189733, X-ray and FUV flares are preferentially in a very restricted range of planetary phases. Matsakos et al. (2015) show, using MHD simulations, planetary gas can be liberated, forming a stream of material that gets compressed and accretes onto the star with a phase lag of 70-90 degrees. This scenario explains many features observed both in X-rays and the FUV (Pillitteri et al. 2015). We have identified several examples of Hot Jupiter hosts which appear too active when compared to their binary companion. On the other hand, WASP-18 - an F6 star with a massive hot Jupiter, shows no signs of activity in X-rays or UV. Several age indicators (isochrone fitting, Li abundance) point to a young age (~0.5 -1.0 Gyr) and thus significant activity was expected. In this system, tidal SPI between the star and the very close-in and massive planet appears to destroy the formation of magnetic dynamo and thus nullify the stellar activity.

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Institution(s): *1. INAF, 2. Queen's University , 3. SAO*

100.02 – The X-ray high resolution Chandra spectra of Nova SMC 2016

Nova SMC 2016 was discovered in the direction of the SMC by the MASTER Global Robotic Net on 2016 October 14. At peak optical magnitude B~9.55, if it is located in the SMC it is one of the intrinsically most luminous novae ever recorded. The X-ray to optical luminosity of the nova is around the average value, so it was also very X-ray luminous for a nova in the SMC. It was classified as a fast nova. It was monitored with Swift until the present day (2017 May), with close cadence whenever it was feasible, and we were able to observe it on the rise to maximum X-ray luminosity on 2016 November 17-18 and at maximum on 2017 January 4 with the Chandra Low Energy Transmission Grating (another high resolution X-ray spectrum was obtained with XMM-Newton on 2016 December 22). We report on the luminous supersoft spectrum of the central source observed with Chandra, a luminous stellar continuum with effective temperature of about 650,000 K in December and 750,000 K in January, with deep absorption features of carbon, nitrogen and sulphur, blue-shifted by about 1700 km/s in November and by 2100 km/s in January. We describe the results of our initial spectral and timing analysis.

Author(s): Marina Orio[2], Elias Aydi[7], Ehud Behar[5], David Buckley[7], Andrej Dobrotka[6], Jan-Uwe Ness[8], Kim L Page[1], Thomas Rauch[4], Polina Zemko[3]
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100.03 – A Hard Look at NS LMXBs with NuSTAR

Through NuSTAR we have been able to perform inner disk measurements that are unbiased by pile-up effects. From these measurements we are able to infer different properties about the neutron star itself, such as magnetic field estimates, the extent of the boundary layer, and constraints to the equation of state. NuSTAR has observed a number of neutron stars over range of Eddington ratios, which has allowed us to probe the extent of the inner disk over a range of mass accretion rates. There does not appear to be a clear trend between mass accretion rate and the location of the inner disk radius. This affirms the results of several previous studies that were complicated by pile-up effects. We compare the magnetic field strengths from reflection modeling methods to those seen for accreting millisecond X-ray pulsars (AMXPs). We find the magnetic field strengths to be consistent with AMXP's over comparable Eddington ratios, though coherent pulsations have not yet been detected for some of these sources. Additionally, we explore possible implications for the equation of state of neutron stars.

Author(s): Renee Ludlam[7], Jon M. Miller[7], Edward Cackett[8], Nathalie Degenaar[5], Andrew C Fabian[2], Michael Parker[2], John Tomsick[6], Matteo Bachetti[1], Didier Barret[4],Lorenzo Natalucci[3]
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100.04 – A potential low-mass black hole in GX 339-4

GX 339-4 is a low mass X-ray binary (LMXB) that has been extensively studied since its discovery. All four X-ray states typically seen in X-ray binaries (XRBs) have been detected in this system, and X-ray observations of its relatively frequent outbursts have been very important in shaping the theory of LMXB outbursts. The relation between X-ray and radio emission from XRBs also relies heavily on observations of this source. However, absorption lines from the donor star in this system had never been detected because even in quiescence, the accretion disc dominates the optical spectrum.
We have for the first time detected absorption lines from the donor star in near-infrared spectra of GX 339-4 obtained with X-shooter on the VLT. We confirm that the donor is a K-type subgiant and measure its radial velocity semi-amplitude to be 219 km/s, much lower than previously determined from the Bowen emission lines. This leads to a mass function of 1.91 ± 0.08 Msun, which means that GX 339-4 could harbor one of the lowest mass black holes known to date.

Author(s): Marianne Heida[1], Peter G Jonker[4], Manuel Torres[2], Andrea Chiavassa[3]
Institution(s): *1. Caltech, 2. IAC, 3. Observatoire de la Cote d'Azur, 4. SRON Netherlands Institute for Space Research*

100.05 – Hyper-luminous Wandering Massive Black Holes Discovered in the XMM-Newton Catalog

Galaxies are believed to assemble through hierarchical merging. The cosmological simulations find that the merging process should leave many wandering massive black holes in galactic halos. Only a few candidates for such objects have been found. We report the discovery of two ultrasoft hyper-luminous off-nuclear X-ray sources from the XMM-Newton catalog. One has a projected offset of ~1 arcsec (5.2 kpc) from the nucleus of an inactive S0 galaxy at a distance of d_L=2.3 Gpc in the Extended Groth Strip. It was serendipitously detected by XMM-Newton and Chandra in 2000-2002, with characteristic temperature of 0.1-0.2 keV and peak X-ray luminosity of 4X10^43 erg/s. It was not detected in our later follow-up observations, implying a long-term flux variation factor of >14. It has a faint optical counterpart candidate of the absolute V-band magnitude of -15.9 AB mag. The other source has a projected offset of 11.6 arcsec (12.4 kpc) from the nucleus of a barred S0 galaxy at d_L=244 Mpc. It has been detected from 2006 to 1016 with systematic decrease in both the X-ray luminosity (from 7X10^42 erg/s to 4X10^41 erg/s) and the characteristic temperature (from 0.28 keV to 0.14 keV). The X-ray outburst was associated with an optical flare, which suggested that the event started before 2005. We discuss various explanations for both sources and find that they are best explained as massive (10^4-10^5 solar mass) black holes embedded in the nucleus of possibly stripped satellite galaxies, with the X-ray outbursts due to tidal disruption of surrounding stars by the black holes.
Author(s): Dacheng Lin[9], Jeroen Homan[4], Eleazar R. Carrasco[1], Natalie Webb[2], Jimmy Irwin[7], Renato A. Dupke[5], Aaron J. Romanowsky[6], Enrico Ramirez-Ruiz[8], Jay Strader[3], Didier Barret[2], Olivier Godet[2], Ronald A. Remillard[4]
Institution(s): *1. Gemini Observatory, 2. IRAP, 3. Michigan State University, 4. MIT, 5. Observatorio Nacional, 6. San Jose State University, 7. University of Alabama, 8. University of California, Santa Cruz, 9. University of New Hampshire*

100.06 – Giant X-ray Flares in Nearby Galaxies

Very rapid (<1 minute), high amplitude (>100) variability at >1e40 erg/s is nearly unprecedented in our Universe. We have recently discovered a new class of X-ray point sources showing such variability in two nearby galaxies while analyzing archival Chandra, XMM-Newton, and Swift data. One source is located within a suspected globular cluster of the host galaxy and flared one time to 1e41 ergs/s, while the other source peaked at 1e40 ergs/s and is located in either a globular cluster of the host galaxy or the core of a stripped dwarf companion galaxy that flared on six occasions over a seven year time span. When not flaring, the sources appear as normal accreting neutron star or black hole X-ray binaries, indicating that the flare event does not significantly disrupt the system. We speculate on the nature of these explosive, yet non-destructive objects.
Author(s): Jimmy Irwin[5], W. Peter Maksym[1], Gregory R. Sivakoff[6], Aaron J. Romanowsky[4], Dacheng Lin[8], Jay Strader[2], Jifeng Liu[3], Jon M. Miller[7]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Michigan State University, 3. NAC, 4. San Jose State University, 5. University of Alabama, 6. University of Alberta, 7. University of Michigan, 8. University of New Hampshire*

101 – AGN in Dwarf Galaxies

101.01 – Black Hole Formation and Growth in a Cosmological Context

Massive black holes (BHs) inhabit local galaxies, from massive to dwarf galaxies. BH formation modeling must account for the properties of BHs in today's galaxies, notably why some galaxies host a BH, and others do not. We have developed an implementation of BH formation in the code Ramses, where BHs form in dense, low-metallicity environments, and BH masses are computed one-by-one on-the-fly. This self-consistent method allows us to study the distribution of BHs in a cosmological context and their evolution over cosmic time.
We find that supernova (SN) feedback is of paramount importance, as it modulates metal enrichment, and the retention of cold gas in low-mass galaxies. Simulations with strong SN feedback, lead to galaxies with stellar masses closer to those predicted by the relation with halo mass. SN feedback also affects the gas supply to BH seed, and their ability to grow: BH growth in low-mass galaxies is stunted by strong SN feedback. The properties of BHs in dwarf galaxies thus remain a testbed for BH formation. Simulations with strong SN feedback produce a population of BHs in better agreement with observational constraints (e.g. bolometric and hard X-ray BH luminosity function, number of observational high redshift AGN candidates).
Author(s): Melanie Habouzit[1]
Institution(s): *1. Center for Computational Astrophysics*

101.02 – Multi-wavelength Searches for Massive Black Holes in Dwarf Galaxies

Contrary to conventional wisdom, low-mass, physically small dwarf galaxies can indeed host massive black holes (BHs). Moreover, the population and properties of BHs in nearby dwarf galaxies hold clues to the formation of the first seed BHs in the earlier Universe. Identifying BHs in dwarf galaxies, however, is challenging. AGNs powered by smaller BHs are less luminous and more difficult to detect than typical AGNs in more massive systems, and low-mass galaxies generally have ongoing star formation, gas and dust that can mimic or mask signatures of BH accretion. With these challenges in mind, I will present ongoing multi-wavelength searches for AGNs in dwarf galaxies, as well as follow-up studies of existing samples. I will also discuss how this work has implications for directly detecting BH activity in the first galaxies at high redshift.

Author(s): Amy E. Reines[1]
Institution(s): *1. Montana State University*

101.03 – Characterizing AGNs in Dwarf Galaxies

Searching for signs of black hole accretion is the best way of identifying black holes in dwarf galaxies. In the last several years, the number of dwarf galaxies with known active galactic nuclei (AGNs) has increased by over an order of magnitude, thanks to large scale surveys such as the Sloan Digital Sky Survey. These objects comprise a new population of AGNs. As such, it is important to characterize this population to understand how they compare to AGN in more massive systems, as well as to determine which factors influence the presence of AGNs in dwarf galaxies. I will discuss X-ray and ultraviolet observations of a sample of dwarf galaxies with optical signatures of AGN activity. I will also report on multi-epoch spectroscopy of dwarf galaxies with optical AGN signatures, and discuss new results from Hubble Space Telescope WFC3 imaging of RGG 118, a dwarf galaxy hosting an actively accreting 50,000 solar mass black hole in its core.

Author(s): Vivienne Baldassare[3], Amy E. Reines[1], Elena Gallo[3], Jenny E. Greene[2]
Institution(s): *1. National Optical Astronomy Observatory, 2. Princeton University, 3. University of Michigan*

101.04 – The X-ray Properties of Million Solar Mass Black Holes

I will present an observational overview on our understanding of accretion onto low-mass black holes (masses ~1e6 Msun or lower). We find that low-mass black holes that are selected by broad optical emission lines show, on average, higher X-ray to optical flux ratios than is observed for quasars powered by supermassive black holes (i.e., masses ~1e8-1e9 Msun). This higher flux ratio can be explained by appealing to mass-scaling arguments for coupled accretion disks/coronae. However, we also find an X-ray weak tail among the population of low-mass black holes. This X-ray weak tail could indicate accretion near the Eddington limit, which would suggest that optical searches for low-mass black holes preferentially select the highest accretion rate objects. I will conclude by discussing how these observational constraints can inform X-ray and radio surveys for lower-mass and lower-accretion rate black holes at the centers of dwarf galaxies, including implications for applying the fundamental plane of black hole activity to such surveys.

Author(s): Richard Plotkin[1], Elena Gallo[3], Amy E. Reines[2]
Institution(s): *1. International Centre for Radio Astronomy Research - Curtin University, 2. NOAO, 3. University of Michigan*

101.05 – X-ray Constraints on the Local Supermassive Black Hole Occupation Fraction

Distinct seed formation mechanisms are imprinted upon the fraction of dwarf galaxies currently containing a central supermassive black hole. Seeding by Population III remnants is expected to produce a higher occupation fraction than is generated with direct gas collapse precursors. Chandra observations of nearby early-type galaxies can directly detect even low-level supermassive black hole activity, and the active fraction immediately provides a firm lower limit to the occupation fraction. We previously used the volume-limited AMUSE surveys of ~200 optically selected early-type galaxies to characterize simultaneously, for the first time, the occupation fraction and the scaling of L_X with M_{star}, accounting for intrinsic scatter, measurement uncertainties, and X-ray limits. The impact of X-ray binary contamination is also quantitatively considered. For early-type galaxies with $M_{star} < 10^{10} M_{\odot}$, we obtained a lower limit to the occupation fraction of >20% (at 95% confidence), but full occupation cannot be excluded. Here, we summarize those findings and also present preliminary results from a new archival study (Wu et al., in preparation) analyzing 326 early-type galaxies; we discuss our improved constraints from this larger sample upon both the occupation fraction and the slope of log L_X with log M_{star}. Finally, we use simulations to explore the precision with which these parameters could be refined with a proposed large Chandra snapshot survey of an additional 312 local early-type galaxies, and/or with future high angular resolution, deep sensitivity samples as delivered by a Lynx-class mission.

Author(s): Brendan P. Miller[1], Jianfeng Wu[2], Elena Gallo[2]
Institution(s): *1. College of St. Scholastica, 2. University of Michigan*

101.06 – Hard X-Ray-selected AGNs in Low-mass Galaxies from the NuSTAR Serendipitous Survey

I will present the properties of the first hard X-ray (>10 keV) low-mass AGN sample selected from the ~13 deg2 NuSTAR Serendipitous Survey. This z<0.3 sample of 10 low-mass AGN has median r-band absolute magnitude and 2-10 keV luminosity comparable to those of broad-line intermediate mass black hole candidates selected from large optical spectroscopic surveys. We find that 30 (+16,- 9)% of the galaxies in our sample do not show AGN-like emission lines in their optical spectra, and one of the ten galaxies in our sample, IC 750, shows evidence for heavy X-ray absorption. This result implies that a non-negligible fraction of low-mass galaxies might harbor accreting massive black holes that are missed by optical spectroscopic surveys and <10 keV X-ray surveys. The mid-IR colors of our sample also indicate that these optically normal low-mass AGNs cannot be efficiently identified with typical AGN selection criteria based on Wide Field Infrared Survey Explorer colors. While the hard X-ray-selected low-mass AGN sample size is still limited, our results show that sensitive NuSTAR observations are capable of probing faint hard X-ray emission originating from the nuclei of low-mass galaxies out to moderate redshift (z< 0.3), thus providing a critical step in understanding AGN demographics in low-mass galaxies.

Author(s): Chien-Ting J. Chen[1]
Institution(s): *1. Pennsylvania State University*

102 – High-Energy and Multiwavelength Polarimetry: Current Status and New Frontiers

102.01 – Session Introduction and the GammaSIG

While gamma-ray instruments allow for a wide range of astrophysics investigations, several current satellite or balloon missions are capable of measuring the polarization of sources. Given the promise of obtaining this new information, the Gamma-ray Science Interest Group (GammaSIG) organized this special session on high-energy (X-ray and gamma-ray) polarimetry. The GammaSIG facilitates gamma-ray related discussions and activities. It is organized by members of the Physics of the Cosmos Program Analysis Group (PhysPAG) executive committee, but membership is open to any member of the astronomy and physics community. In this shortpresentation, I will describe the activities that the GammaSIG is organizing, explain how people can get involved, and then provide an introduction to the session.

Author(s): John Tomsick[1], Henric Krawczynski[2]
Institution(s): *1. UC Berkeley/SSL, 2. Washington University, St. Louis*

102.02 – The Imaging X-ray Polarimetry Explorer: IXPE

The Imaging X-ray Explorer (IXPE) will be the next in the line of NASA's Small Explorer Missions. The mission allows, for the first time imaging X-ray polarimetry with sufficient sensitivity to meaningfully study approximately 50 X-ray sources per year of observing. The most unique feature of this mission provides image-resolved polarization measurements for a significant number of extended objects such as supernova remnants and pulsar wind nebulae. The imaging capability will also be exploited to accomplish a unique study of our galactic center to understand if SGR-A* was substantially more active several hundred years ago. The sensitivity also allows one to perform the first X-ray polarization map of the bright active galaxy Cen- A.

The mission is a partnership with the Italian Space Agency and NASA and involves several institutions in Italy with the Italian partners providing the polarization-sensitive X-ray detectors and the use of the ground station at Malindi. The IAPS/INAF at Rome and INFN in Pisa and Turin will lead the detector development. Ball Aerospace, in Boulder Colorado, will build the spacecraft and perform systems integration. NASA's Marshall Space Flight Center leads the program and will supply the X-ray Telescopes, use its facilities to perform end-to-end X-ray calibration and provide the Science Operations Center. Mission operations will be conducted at the Laboratory for Atmospheric Physics (LASP), also in Boulder Colorado.

Author(s): Martin C. Weisskopf[1]
Institution(s): *1. NASA/MSFC*

102.03 – Integral Observations of Gamma-Ray Polarized Sources

In complement to spectro-imaging observations, gamma-ray polarimetry provides a unique in-sight into the geometry and magnetic configuration of compact gamma-ray sources, such as neutron stars or black holes. Due to the unprecedented spectral and timing capabilities of Integral, and thanks to its coded mask imaging technics, which efficiently suppresses most of the background contribution, we have measured linearly polarized emission from the brightest cosmic high energy sources. We were able to measure for the first time, at energies above 200 keV, a clear signal from several gamma-ray sources such as the Crab pulsar, the black hole candidate Cygnus X-1, and Gamma-Ray Bursts. These observations have enabled us to put strong constraints on the physical process at work in these sources. After a short review of Compton polarimeter principles and INTEGRAL polarimetric data analysis, I will describe these Integral results and their implication on our knowledge of compact objects.

Author(s): Philippe Laurent[1]
Institution(s): *1. CEA/DSM/IRFU/SAp and APC*

102.04 – POLAR, a wide field compact detector for polarization measurements of hard X-rays from
Gamma Ray Bursts on board of the Tiangong 2 Chinese space station

POLAR is an homogeneous wide field Compton polarimeter using plastic scintillators and multichannel photomultipliers. It was calibrated precisely in a polarized beam. It was sent in space on September 15 2016 on top of the Tiangong2 Chinese space station. Some details on construction and calibration will be presented as well as some preliminary results on performance in space and results.

Author(s): Nicolas Produit[1]
Institution(s): *1. University of Geneva*

102.05 – Results from 2016 X-Calibur flight and future prospects for hard X-ray polarimetry

Hard X-ray polarimetric observations at >25 keV energies with a balloon borne experiment like X-Calibur will complement the <10 keV polarimetric results obtained with NASA's IXPE mission experiment in an ideal way. For example, the measurements of the polarization of the >10 keV emission from stellar-mass black holes will constrain the corona geometry and will help to use the <10 keV spectropolarimetric results to measure the black hole spin. During the 2016 test flight X-Calibur observed the Crab nebula, Cyg X-1, and Sco X-1. Although the flight allowed us to validate the pointing and detector functionality, the rather short observations at sub-optimal elevations partially at low float altitudes and with a sub-optimal detector configuration did not yield sensitive constraints on the polarization properties. The experiment is scheduled for a long duration balloon (LDB) flight from McMurdo (Antarctica) in December 2018/Janurary 2019. The longer exposure times afforded by an LDB flight will provide the first hard X-ray polarization measurements of Vela X-1, 4U 1700-377, GX 301-2, Cen A, and flaring target-of-opportunity sources.

Author(s): Fabian Kislat[1]
Institution(s): *1. Washington University in St. Louis*

102.06 – Exploring Astrophysical Gamma Ray Polarization with COSI

Astrophysical polarization measurements provide unique diagnostics for determining emission mechanisms and source geometries (e.g., magnetic field, accretion disk, and jet), but current gamma-ray results give just a glimpse into the potential for what we can learn. The Compton Spectrometer and Imager (COSI) wide-field gamma-ray telescope (0.2-5 MeV) is designed to perform pioneering studies of gamma-ray polarization. Compton telescopes are inherently sensitive to linear polarization. Compact designs (like COSI vs. COMPTEL) maximize the efficiency for detecting photons scattered at ~90° which are the most highly modulated, resulting in excellent sensitivity to polarization. COSI underwent a successful 46-day science flight in 2016 on NASA's 18 MCF superpressure balloon, the first science payload to launch from New Zealand. During the flight, COSI detected several sources for which polarization measurements are feasible, including the bright, long-duration gamma-ray burst GRB 160530A. I will discuss the polarization performance, polarization analysis results for GRB 160530A, and the future polarization goals for the COSI program.

Author(s): Alexander Lowell[1]
Institution(s): *1. UC Berkeley*

102.07 – Polarization measurement for bright hard X-ray sources with CZT-Imager (CZTI) onboard AstroSat

CZT-Imager (CZTI) onboard AstroSat, has been operational since 6th October 2015. Consisted of an array of pixelated CZT detectors resulting in a total collecting area of 976 cm^2, CZTI is primarily a hard X-ray spectroscopic instrument but provides sensitive polarization measurements from the Compton events detected in the adjacent pixels in the energy range of ~100 - 350 keV. Two potential targets for CZTI polarimetry are Crab pulsar and Cygnus X-1. Crab has been observed for 800 ks by CZTI after launch and the results indicate detection of statistically significant polarization of 32% for all-Crab and 40% for the off-pulse. We also achieved promising results from phase resolved polarimetry of the pulsed radiation of Crab. Cygnus X-1, the black hole XRB has been observed for ~500 ks by CZTI. Preliminary results for Cygnus X-1 is also encouraging. Because of the increasing transparency of CZTI support structure, CZTI works as a wide angle hard X-ray monitor providing an unique opportunity for GRB detection and polarization measurement. In one year after launch, total 47 GRBs have been detected by CZTI, among which 11 bright GRBs show a clear and statistically significant polarization signature. I would briefly present these findings from CZTI.

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103 – Missions & Instruments Poster Session

103.01 – Fabrication of blazed gratings for X-ray spectroscopy using substrate conformal imprint lithography

The majority of spectral lines relevant in high energy astrophysics exist at soft X-ray energies, where gratings dominate over microcalorimeters. Next-generation reflection gratings have been identified as a key technology to improve the spectroscopic capabilities of future X-ray observatories. Currently, the grating fabrication process centers on the production of a large-area (72 cm^2) master template through techniques in electron-beam lithography, plasma etching and anisotropic wet etching in single-crystal Si. Then, many replicas are produced to populate a grating array, which intercepts and disperses the radiation coming to a focus in a Wolter-I telescope. Of importance is implenting a replication procedure that preserves the fidelity of the master grating template at a low cost. Traditionally, the Si master template has been used to stamp directly into a UV-curable resist coated on a fused silica substrate through the process of nanoimprint lithography (UV-NIL). Though the high stiffness of Si allows the desired inverse of the original pattern to be imprinted with high resolution, difficulties arise especially when imprinting over a large area. Substrate conformal imprint lithography (SCIL) is a relatively new commercial process intended to evade these problems. In contrast to UV-NIL, the SCIL process uses a flexible stamp formed from the master template for imprinting. The flexible stamp carries the inverse of the original pattern in a modified silicone rubber, which has increased stiffness compared to standard silicone used in soft lithography processes. This enables the positive of original pattern to be imprinted sequentially with high resolution while confroming to the bow of the substrate and reducing damage due to particulate contaminants. The desired inverse of the original pattern can be imprinted with SCIL by forming a second flexible stamp from the initial flexible stamp. Further, SCIL is compatible with an inorganic imprint resist that has been found to exhibit sub-nm RMS roughness when coated with Cr/Au for reflectivity. Here, data gathered from the Advanced Light Source characterizing the efficiency of the original Si grating and the non-inverted and inverted SCIL replicas are presented.

Author(s): Jake McCoy[2], Marc Verschuuren[1], Gerald Lopez[3], Ningxiao Zhang[2], Randall McEntaffer[2]
Institution(s): *1. Philips SCIL Solutions, 2. The Pennsylvania State University, 3. The University of Pennsylvania*

103.02 – Progress in reflection grating spectrometers for X-ray astrophysics

Soft X-ray spectroscopy can address future science goals pertaining to understanding the cycle of hot baryons in the universe. Detailing feedback processes in galaxies, mapping the distribution of baryons in the circum- and intergalactic medium, and unraveling unknowns in stellar life cycles places demanding requirements upon spectrometers. Here, we detail advancements in reflection grating technologies that can be used to help provide answers to these important questions. We also discuss possible applications including a configuration for the Lynx concept strategic mission.

Author(s): Randall L. McEntaffer[1]
Institution(s): *1. Pennsylvania State University*

103.03 – High Precision 2-D Grating Groove Density Measurement

Our research group at Penn State University is working on producing X-ray reflection gratings with high spectral resolving power and high diffraction efficiency. To estimate our fabrication accuracy, we apply a precise 2-D grating groove density measurement to plot groove density distributions of gratings on 6-inch wafers. In addition to plotting a fixed groove density distribution, this method is also sensitive to measuring the variation of the groove density simultaneously. This system can reach a measuring accuracy ($\Delta N/N$) of 10^{-3}. Here we present this groove density measurement and some applications.

Author(s): Ningxiao Zhang[1], Randall McEntaffer[1], Ross Tedesco[1]
Institution(s): *1. Penn State University*

103.04 – X-ray verification of an optically-aligned off-plane grating module

The next generation of X-ray spectrometer missions are baselined to have order-of-magnitude improvements in both spectral resolving power and effective area when compared to existing X-ray spectrometer missions. Off-plane X-ray reflection gratings are capable of achieving high resolution and high diffraction efficiencies over the entire X-ray bandpass, making them an ideal technology to implement on these future missions. To achieve the high effective area desired while maintaining high spectral resolution, many off-plane gratings must be precisely aligned such that their diffraction arcs overlap at the focal plane. Methods are under development to align a number of these gratings into a grating module using optical metrology techniques in support of the Off-plane Grating Rocket Experiment (OGRE), a suborbital rocket payload scheduled to launch in late 2018. X-ray testing was performed on an aligned grating module at the Straylight Test Facility (SLTF) at NASA Marshall Space Flight Center (MSFC) to assess the current alignment methodology and its ability to meet the desired performance of OGRE. We report on the results from the test campaign at MSFC, as well as plans for future development.

Author(s): Benjamin Donovan[3], Randall McEntaffer[3], James Tutt[3], Casey DeRoo[1], Ryan Allured[1], Jessica Gaskin[2], Jeffery Kolodziejczak[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. NASA Marshall Space Flight Center, 3. Pennsylvania State University*

103.05 – Alignment of off-plane X-ray reflection gratings using optical light

The next generation of high resolution soft X-ray spectrometers require large effective areas and high resolving capability. This can be achieved through the use of off-plane reflection gratings. X-rays will only reflect if they are incident onto a surface at a shallow graze angle; therefore, arrays of off-plane gratings are placed into the converging beam of a telescope to achieve the necessary effective area. To maintain the high resolving power of a single grating across this array, the gratings have to be very precisely aligned to one another and fanned so that they match the convergence of the telescope.

Leveraging previous work that co-aligned 4 state of the art gratings into a module, 26 gratings will be co-aligned into a module that will be launched on the sub-orbital rocket WRX-R. The alignment procedure is unchanged, but improvements have been made to stabilize the setup. The alignment procedure was found to be highly temperature dependent and the opto-mechanics suffered from mechanical instabilities. To solve these issues, the new setup uses a high precision temperature control unit and a larger optical bench allowing the setup to be simplified.

The alignment method is based around the generation of a light wavefront which reflects off the grating surface. This wavefront is measured using a Shack-Hartmann sensor, which allows the gratings orientation relative to the sensor normal to be found. A hexapod is then used to move the grating, allowing the grating surface to be aligned in pitch, roll and yaw. The x, y and z positions for each grating are constrained through the mechanical tolerance of the alignment mount and high precision stages. The aligned gratings are mounted into an Invar module and a theodolite is used to measure the relative position of the module to the known position of the grating.

This poster discusses the improvements made to the grating alignment process and the proposed path towards producing the array of 26 co-aligned gratings that will be used on WRX-R.

Author(s): James Tutt[2], Randall McEntaffer[2], Benjamin Donovan[2], Ted Schultz[2], Casey DeRoo[1], Edward Hertz[1], Ryan Allured[1]
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103.06 – The Quality and Stability of Chandra Telescope Spacial Resolution

Chandra X-ray Observatory revolutionized the X-ray astronomy as being the first, and so far the only, X-ray telescope achieving sub-arcsecond spacial resolution. Chandra is comprised of three principal elements: the High Resolution Mirror Assembly (HRMA), Pointing Control and Aspect Determination (PCAD) system, and the Science Instrument Module (SIM), which is where the X-ray detectors mounted and is connected to the HRMA by a 10-meter long Optical Bench Assembly. To achieve and retain the unprecedented imaging quality, it is critical that these three principal elements to stay rigid and stable for the entire life time of the Chandra operation. I will review the issues of telescope pointing stability, optical Axis, aimpoint and their impacts to the Chandra operation, and evaluate the integrity and stability of the telescope. I will show images taken from all four detectors since launch to demonstrate the quality and stability of the Chandra spacial resolution.

Author(s): Ping Zhao[1]
Institution(s): *1. Harvard-Smithsonian, CfA*

103.07 – Backgrounds, radiation damage, and spacecraft orbits

The scientific utility of any space-based observatory can be limited by the on-orbit charged particle background and the radiation-induced damage. All existing and proposed missions have had to make choices about orbit selection, trading off the radiation environment against other factors. We present simulations from ESA's SPace ENVironment Information System (SPENVIS) of the radiation environment for spacecraft in a variety of orbits, from Low Earth Orbit (LEO) at multiple inclinations to High Earth Orbit (HEO) to Earth-Sun L2 orbit. We summarize how different orbits change the charged particle background and the radiation damage to the instrument. We also discuss the limitations of SPENVIS simulations, particularly outside the Earth's trapped radiation and point to new resources attempting to address those limitations.

Author(s): Catherine E. Grant[1], Eric D. Miller[1], Mark W. Bautz[1]
Institution(s): *1. MIT Kavli Institute*

103.08 – Optical Communication on SmallSats – Enabling the Next Era in Space Science (a Keck Institute for Space Studies Workshop)

Small satellites (<50 kg) have revolutionized the possibilities for inexpensive science from space-borne platforms. A number of scientific CubeSats have been recently launched or are under development, including some bound for interplanetary space. Recent miniaturization of technology for high-precision pointing, high efficiency solar power, high-powered on-board processing, and scientific detectors provide the capability for groundbreaking, focused science from these resource-limited spacecraft. Similar innovations in both radio frequency and optical/laser communications are poised to increase telemetry bandwidth to a gigabit per second (Gb/s) or more. This enhancement can allow real-time, global science measurements and/or ultra-high fidelity (resolution, cadence, etc.) observations from tens or hundreds of Earth-orbiting satellites, or permit high-bandwidth, direct-to-earth communications for (inter)planetary missions. Here we present the results of a recent Keck Institue for Space Science workshop that brought together scientists and engineers from academia and industry to showcase the breakthrough science enabled by optical communications on small satellites for future missions.

Author(s): Brian Grefenstette[1]

Institution(s): *1. Caltech*

103.09 – Toward Fast, Low-noise, Low-power, Small Pixel Digital CCDs for X-ray Astronomy

Future X-ray missions such as Lynx will require large-format imaging detectors with spectroscopic performance at least as good as the best current-generation devices but with much higher readout rates. We have been investigating a detector architecture under development at MIT Lincoln Laboratory, called the Digital CCD, for use in such missions. The Digital CCD is envisioned as a CMOS-compatible detector integrated with parallel CMOS signal processing chains. The combination of fast, low noise CCD amplifiers with highly parallel signal processing offers the high frame-rate required. The CMOS-compatibility of the CCD provides low-power charge transfer.

Here we report on the X-ray spectral response of a CMOS-compatible test CCD read at 2.5 MHz (about 25 times faster than the CCDs operating on Chandra ACIS), using transfer clock levels of only +-1 V (power per unit area less than 25 times that of ACIS CCDs). The 8-micron pixels of this device are one third the size of those on Chandra ACIS. We compare charge splitting in this detector with that observed in larger-pixel detectors, and we briefly discuss the implications of the small-pixel, deep-depletion detector configurations required by Lynx.

Author(s): Mark W. Bautz[1], Barry Burke[2], Michael Cooper[2], Richard Foster[1], Catherine E. Grant[1], Beverly LaMarr[1], Andrew Malonis[1], Eric D. Miller[1], Gregory Prigozhin[1],Daniel Schuette[2]
Institution(s): *1. MIT, 2. MIT Lincoln Laboratory*

103.10 – Development of Cadmium Telluride Detectors for Hard X-ray Astronomy

We present findings on the development of hybrid Cadmium Telluride (CdTe) detectors for applications in space-based X-ray astronomy. In addition to presenting the components and design of the detectors, which consist of 2cm × 2cm × 2mm CdTe crystals mounted on a custom ASIC, we also determine their viability for scientific applications. We present results of spectral calibration using ^{57}Co, ^{155}Eu, and ^{241}Am sources, noise calibration, as well as optimal operating conditions including temperature, guard ring voltage, and bias voltage. By comparing these CdTe detectors to previous generations of detectors, in particular the Cadmium Zinc Telluride (CZT) detectors launched onboard NuSTAR in 2012, we hope to show that hybrid CdTe detectors are uniquely suited to high-resolution X-ray astronomy above the energy ranges of current comparable observatories.

Author(s): Sean Pike[1], Fiona Harrison[1], Jill Burnham[1], Rick Cook[1], Brian Grefenstette[1], Kristin Madsen[1], Hiromasa Miyasaka[1], Vikram Rana[1]
Institution(s): *1. California Institute of Technology*

103.11 – X-ray Hybrid CMOS Detectors : Recent progress in development and characterization

PennState high energy astronomy laboratory has been working on the development and characterization of Hybrid CMOS Detectors (HCDs) for last few years in collaboration with Teledyne Imaging Sensors (TIS). HCDs are preferred over X-ray CCDs due to their higher and flexible read out rate, radiation hardness and low power which make them more suitable for next generation large area X-ray telescopic missions. An H2RG detector with 36 micron pixel pitch and 18 micron ROIC, has been selected for a sounding rocket flight in 2018. The H2RG detector provides ~2.5 % energy resolution at 5.9 keV and ~7 e- read noise when coupled to a cryo-SIDECAR. We could also detect a clear Oxygen line (~0.5 keV) from the detector implying a lower energy threshold of ~0.3 keV. Further improvement in the energy resolution and read noise is currently under progress. We have been working on the characterization of small pixel HCDs (12.5 micron pixel; smallest pixel HCDs developed so far) which is important for the development of next generation high resolution X-ray spectroscopic instrument based on HCDs. Event recognition in HCDs is another exciting prospect which have been successfully shown to work with a 64 X 64 pixel prototype SPEEDSTAR-EXD which use comparators at each pixel to read out only those pixels having detectable signal, thereby providing an order of magnitude improvement in the read out rate. Currently, we are working on the development of a large area SPEEDSTAR-EXD array for the development of a full fledged instrument. HCDs due to their fast read out, can also be explored as a large FOV instrument to study GRB afterglows and variability and spectroscopic study of other astrophysical transients. In this context, we are characterizing a Lobster-HCD system at multiple energies and multiple off-axis angles for future rocket or CubeSate experiments. In this presentation, I will briefly present these new developments and experiments with HCDs and the analysis techniques.

Author(s): Tanmoy Chattopadhyay[1], Abraham Falcone[1], David N. Burrows[1]
Institution(s): *1. PennState University*

103.12 – The Compton Spectrometer and Imager: Results from the 2016 Super-Pressure Balloon Campaign

The Compton Spectrometer and Imager is a 0.2-5 MeV Compton telescope capable of imaging, spectroscopy and polarimetry of astrophysical sources. Such capabilities are made possible by COSI's twelve germanium cross-strip detectors, which provide for high efficiency, high resolution spectroscopy, and precise 3D positioning of photon interactions. In May 2016, COSI took flight from Wanaka, New Zealand on a NASA super-pressure balloon. For 46 days, COSI floated at a nominal altitude of 33.5 km, continually telemetering science data in real-time. The payload made a safe landing in Peru, and the hard drives containing the full raw data set were recovered. Analysis efforts have resulted in detections of various sources such as the Crab Nebula, Cyg X-1, Cen A, Galactic Center e+e- annihilation, and the long duration gamma-ray burst GRB 160530A. In this presentation, I will provide an overview of our main results, which include measuring the polarization of GRB 160530A, and our image of the Galactic Center at 511 keV. Additionally, I will summarize results pertaining to our detections of the Crab Nebula, Cyg X-1, and Cen A.

Author(s): Alexander Lowell[5], Steven Boggs[6], Jeng-Lun Chiu[5], Carolyn Kierans[5], Clio Sleator[5], John Tomsick[5], Andreas Zoglauer[5], Mark Amman[3], Hsiang-Kuang Chang[4],Chao-Hsiung Tseng[4], Chien-Ying Yang[4], Chih H Lin[1], Pierre Jean[2], Peter von Ballmoos[2]
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103.13 – All-Sky Medium Energy Gamma-ray Observatory (AMEGO) - A discovery mission for the MeV gamma-ray band

The MeV domain is one of the most underexplored windows on the Universe. From astrophysical jets and extreme physics of compact objects to a large population of unidentified objects, fundamental astrophysics questions can be addressed by a mission that opens a window into the MeV range. AMEGO is a wide-field gamma-ray telescope with sensitivity from ~200 keV to >10 GeV. AMEGO provides three new capabilities in MeV astrophysics: sensitive continuum spectral studies, polarization measurments, and nuclear line spectroscopy. AMEGO will consist of four hardware subsystems: a double-sided silicon strip tracker with analog readout, a segmented CZT calorimeter, a segmented CsI calorimeter and a plastic scintillator anticoincidence detector, and will operate primarily in an all-sky survey mode. In this presentation we will describe the AMEGO mission concept and scientific performance.

Author(s): Julie E. McEnery[1]
Institution(s): *1. NASA's GSFC*

103.14 – AMEGO as a supernova alarm: alert, probe and diagnosis of Type Ia explosions

A Type Ia supernova (SNIa) could go entirely unnoticed in the Milky Way and nearby starburst galaxies, due to the large optical and near-IR extinction in the dusty environment, low radio and X-ray luminosities, and a weak neutrino signal. But the recent SN2014J confirms that Type Ia supernovae emit γ-ray lines from 56Ni → 56Co → 56Fe radioactive decay, spanning 158 keV to 2.6 MeV. The Galaxy and nearby starbursts are optically thin to γ-rays, so the supernova line flux will suffer negligible extinction. The All-Sky Medium Energy Gamma-ray Observatory (AMEGO) will monitor the entire sky every 3 hours from ~200 keV to >10 GeV. Most of the SNIa gamma-ray lines are squarely within the AMEGO energy range. Thus AMEGO will be an ideal SNIa monitor and early warning system. We will show that the supernova signal is expected to emerge as distinct from the AMEGO background within days after the explosion in the SN2014J shell model. The early stage observations of SNIa will allow us to explore the progenitor types and the nucleosynthesis of SNIa. Moreover, with the excellent line sensitivity, AMEGO will be able to detect the SNIa at a rate of a few events per year and will obtain enough gamma-ray observations over the mission lifetimes (~10 SNIa) to sample the SNIa. The high SNIa detection rate will also enable the precise measurement of the 56Ni mass generated during the Type Ia explosion, which will help us test the cosmic distance calibration and probe the cosmic acceleration.

Author(s): Julie E. McEnery[1], Xilu Wang[2]
Institution(s): *1. NASA's GSFC, 2. University of Illinois at Urbana-Champaign*

103.15 – Gamma-ray Burst and Gravitational Wave Counterpart Prospects in the MeV Band with AMEGO

The All-sky Medium Energy Gamma-ray Observatory (AMEGO) Probe mission concept is uniquely suited to address open questions in Gamma-ray Burst (GRB) science including the search for counterparts to gravitational-wave events. AMEGO is a wide field of view instrument (~60 deg radius) with a broad energy range (~200 keV to >10 GeV) and excellent continuum sensitivity. The sensitivity improvement will allow for probes of GRB emission mechanisms and jet composition in ways that have not been accessible with previous instruments. Potential for polarization measurement may also have profound impacts on the understanding of GRB mechanisms. AMEGO will also be an excellent facility for the search for gravitational wave counterparts to binary mergers including at least one neutron star, which are thought to produce short duration GRBs. This poster will describe how the AMEGO will advance these fields.

Author(s): Judith L. Racusin[1]
Institution(s): *1. NASA/GSFC*

103.16 – Exploring Galactic Particle Accelerators with the All-sky Medium Energy Gamma-Ray Observatory (AMEGO)

Observations with the Fermi Large Area Telescope have raised new questions about particle accelerators within the Galaxy, including supernova remnants, pulsar wind nebulae, and novae. What is the origin and mechanism of the extreme, rapid variability seen in the Crab Nebula and how does it connect to longer time-scale hard X-ray variability? Do other young PWNe show this behavior near the synchrotron cutoff energy, which more commonly falls in the MeV band? How does the gamma-ray emission routinely detected from a nova relate to the properties of the binary system and the particle acceleration process occurring in the outburst? Can prompt gamma signals from novae be detected to probe the onset of the thermonuclear runaway explosion? MeV observations will also provide an important extension below the pion decay feature in LAT-detected supernova remnants as well as providing sensitivity to the youngest SNRs in the Galaxy and the LMC. We will explore the impact of medium-energy gamma-ray observations on characterizing known acceleration regions and exploring new, currently inaccessible phenomena.

Author(s): Elizabeth A. Hays[1]
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103.17 – Exploring the particle nature of dark matter with the All-sky Medium Energy Gamma-ray Observatory (AMEGO)

The era of precision cosmology has revealed that ~80% of the matter in the universe is dark matter. Two leading candidates, motivated by both particle and astrophysics, are Weakly Interacting Massive Particles (WIMPs) and Weakly Interacting Sub-eV Particles (WISPs) like axions and axionlike particles. Both WIMPs and WISPs have distinct gamma-ray signatures. Data from the Fermi Large Area Telescope (Fermi-LAT) continues to be an integral part of the search for these dark matter signatures spanning the 50 MeV to >300 GeV energy range in a variety of astrophysical targets. Thus far, there are no conclusive detections; however, there is an intriguing excess of gamma rays associated with Galactic center (GCE) that could be explained with WIMP annihilation. The angular resolution of the LAT at lower energies makes source selection challenging and the true nature of the detected signal remains unknown. WISP searches using, e.g. supernova explosions, spectra of blazars, or strongly magnetized environments, would also greatly benefit from increased angular and energy resolution, as well as from polarization measurements. To address these, we are developing AMEGO, the All-sky Medium Energy Gamma-ray Observatory. This instrument has a projected energy and angular resolution that will increase sensitivity by a factor of 20-50 over previous instruments. This will allow us to explore new areas of dark matter parameter space and provide unprecedented access to its particle nature.

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103.18 – Gamma-ray Polarimetry with the All-sky Medium Energy Gamma-ray Observatory (AMEGO)

The All-sky Medium Energy Gamma-ray Observatory (AMEGO) is a next-generation Compton and pair-production telescope. It will allow us to perform sensitive polarimetric observations in the 200keV to 3MeV energy range. Due to its wide field of view it will survey the entire sky every 3 hours, enabling polarization measurements not only of persistent, but also of transient sources such as gamma-ray bursts. The polarization of gamma-rays carries geometric information about compact emission regions that are too small to be imaged at any wavelength, and will thus provide qualitatively new insights. In this paper we discuss AMEGO's polarization sensitivity based on detailed simulations of the instrument. We will use these results to discuss the scientific potential of AMEGO to search for violations of Lorentz invariance. Finally, we present predictions for possible observations based on theoretical models of bright gamma-ray bursts, blazar jets, and the high-energy tail of the galactic black hole binary Cygnus X-1. These predictions will demonstrate AMEGO's ability to distinguish different theoretical models.

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Institution(s): *1. Washington University in St. Louis*

103.19 – The Water Recovery X-ray Rocket (WRX-R)

The Water Recovery X-ray Rocket (WRX-R) is a diffuse soft X-ray spectrometer that will launch on a sounding rocket from the Kwajalein Atoll. WRX-R has a field of view of >10 deg^2 and will observe the Vela supernova remnant. A mechanical collimator, state-of-the-art off-plane reflection grating array and hybrid CMOS detector will allow WRX to achieve the most highly-resolved spectrum of the Vela SNR ever recorded. In addition, this payload will fly a hard X-ray telescope that is offset from the soft X-ray spectrometer in order to observe the pulsar at the center of the remnant. We present here an introduction to the instrument, the expected science return, and an update on the state of the payload as we work towards launch.

Author(s): Drew Miles[1]
Institution(s): *1. Pennsylvania State University*

103.20 – LEAP - A Large Area GRB Polarimeter for the ISS

The LargE Area burst Polarimeter (LEAP) is a mission concept for a wide FOV Compton scatter polarimeter instrument that would be mounted as an external payload on the International Space Station (ISS) in 2022. It has recently been proposed as an astrophysics Mission of Opportunity (MoO), with the primary objective of measuring polarization of the prompt emission of Gamma Ray Bursts (GRBs). It will achieve its science objectives with a simple mission design that features a single instrument based entirely on well-established, flight-proven scintillator-photomultiplier tube (PMT) technologies. LEAP will provide GRB polarization measurements from 30–500 keV and GRB spectroscopy from 5 keV up to 5 MeV, and will self-sufficiently provide the source localization that is required for analysis of the polarization data. The instrument consists of 9 independent polarimeter modules and associated electronics. Each module is a 12 x 12 array of independent plastic and CsI(Tl) scintillator elements, each with individual PMT readout, to identify and measure Compton scatter events. It will provide coverage of GRB spectra over a range that includes most values of E_p. With a total geometric scintillator area of 5000 cm^2, LEAP will provide a total effective area for polarization (double scatter) events of ~500 cm^2. LEAP will trigger on >200 GRBs within its FOV during a two-year mission. At least 120 GRBs will have sufficient counts to enable localization with an error of <10°. LEAP will detect (in a 2-year mission) ~75 GRBs with a Minimum Detectable Polarization (MDP) better than 30%. If GRBs are polarized at levels >50%, as suggested by published results, LEAP will provide definitive polarization measurements on ~100 GRBs. These data will allow LEAP to differentiate between the intrinsic and geometric classes of GRB models and further distinguish between two geometric models at the 95% confidence level. Detailed time-resolved and/or energy-resolved studies will be conducted for the brightest GRBs.

Author(s): Mark L. McConnell[20], Matthew G. Baring[13], Peter F. Bloser[20], Michael Stephen Briggs[17], Valerie Connaughton[10], Joseph Dwyer[20], Jessica Gaskin[10], J. Eric Grove[11], Shuichi Gunji[21], Dieter Hartmann[2], Kiyoshi Hayashida[12], Joanne E. Hill[9], R. Marc Kippen[8], Shunji Kishimoto[6], Yuji Kishimoto[6], John F Krizmanic[9], Christoffer Lundman[3], David Mattingly[20], Sheila McBreen[16], Charles A. Meegan[10], Tatehiro Mihara[14], Takeshi Nakamori[21], Mark Pearce[7], Bernard Phlips[11], Robert D. Preece[17], Nicolas Produit[18], James M. Ryan[20], Felix Ryde[7], Takanori Sakamoto[1], Mark Samuel Strickman[11], Steven J. Sturner[9], Hiromitsu Takahashi[4], Kenji Toma[15], W. Thomas Vestrand[8],Colleen A. Wilson-Hodge[10], Yoichi yatsu[22], Daisuke Yonetoku[5], Bing Zhang[19]
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103.21 – The High-Energy X-ray Probe (HEX-P)

The High-Energy X-ray Probe (HEX-P) is a probe-class (~$500M) next-generation high-energy X-ray observatory with broadband (2-200 keV) response and ~40 times the sensitivity of any previous mission in the 10-80 keV band, and >500 times the sensitivity of any previous mission in the 80-200 keV band. Intended to launch contemporaneously with Athena, HEX-P will provide fundamental new discoveries that range from resolving ~90% of the X-ray background at its peak, to measuring the cosmic evolution of black hole spin, to studying faint X-ray populations in nearby galaxies. Based on NuSTAR heritage, HEX-P requires only modest technology development, and could easily be executed within the next decade.

Author(s): Kristin Madsen[1], Fiona Harrison[1], Daniel Stern[1], Brian Grefenstette[1], Vikram Rana[1], Hiromasa Miyasaka[1]
Institution(s): *1. Caltech*

103.22 – Transient Astrophysics Probe

Transient Astrophysics Probe (TAP), selected by NASA for a funded Concept Study, is a wide-field high-energy transient mission proposed for flight starting in the late 2020s. TAP's main science goals, called out as Frontier Discovery areas in the 2010 Decadal Survey, are time-domain astrophysics and counterparts of gravitational wave (GW) detections. The mission instruments include unique imaging soft X-ray optics that allow ~500 deg^2 FoV in each of four separate modules; a high sensitivity, 1 deg^2 FoV soft X-ray telescope based on single crystal silicon optics; a passively cooled, 1 deg^2 FoV Infrared telescope with bandpass 0.6-3 micron; and a set of ~8 small NaI gamma-ray detectors. TAP will observe many events per year of X-ray transients related to compact objects, including tidal disruptions of stars, supernova shock breakouts, neutron star bursts and superbursts, and high redshift Gamma-Ray Bursts. Perhaps most exciting is TAP's capability to observe X-ray and IR counterparts of GWs involving stellar mass black holes detected by LIGO/Virgo, and possibly X-ray counterparts of GWs from supermassive black holes, detected by LISA and Pulsar Timing Arrays.

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

103.23 – The Advanced X-ray Imaging Satellite (AXIS)

The Advanced X-ray Imaging Satellite (AXIS) will follow in the footsteps of the spectacularly successful Chandra X-ray Observatory with similar or higher angular resolution and an order of magnitude more collecting area in the 0.3-10keV band. These capabilities will enable major advances in many of the most active areas of astrophysics, including (i) mapping event horizon scale structure in AGN accretion disks and the determination of supermassive black hole (SMBH) spins through monitoring of gravitationally-microlensed quasars; (ii) dramatically deepening our understanding of AGN feedback in galaxies and galaxy clusters out to high-z through the direct imaging of AGN winds and the interaction of jets with the hot interstellar/intracluster medium; (iii) understanding the fueling of AGN by probing hot flows inside of the SMBH sphere of influence; (iv) obtaining geometric distance measurements using dust scattering halos. With a nominal 2028 launch, AXIS will be enormously synergistic with LSST, ALMA, WFIRST and ATHENA, and will be a valuable precursor to Lynx. AXIS is enabled by breakthroughs in the construction of light-weight X-ray optics from mono-crystalline silicon blocks, building on recent developments in the semiconductor industry. Here, we describe the straw-man concept for AXIS, some of the high profile science that this observatory will address, and how you can become involved.

Author(s): Christopher S. Reynolds[1], Richard Mushotzky[1]
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103.24 – STROBE-X: X-ray Timing & Spectroscopy on Dynamical Timescales from Microseconds to Years

We describe a probe-class mission concept that provides an unprecedented view of the X-ray sky, performing timing and 0.2-30 keV spectroscopy over timescales from microseconds to years. The Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays (STROBE-X) comprises three primary instruments. The first uses an array of lightweight optics (3-m focal length) that concentrate incident photons onto solid state detectors with CCD-level (85-130 eV) energy resolution, 100 ns time resolution, and low background rates to cover the 0.2-12 keV band. This technology is scaled up from NICER, with enhanced optics to take advantage of the longer focal length of STROBE-X. The second uses large-area collimated silicon drift detectors, developed for ESA's LOFT, to cover the 2-30 keV band. These two instruments each provide an order of magnitude improvement in effective area compared with its predecessor (NICER and RXTE, respectively). Finally, a sensitive sky monitor triggers pointed observations, provides high duty cycle, high time resolution, high spectral resolution monitoring of the X-ray sky with ~20 times the sensitivity of the RXTE ASM, and enables multi-wavelength and multi-messenger studies on a continuous, rather than scanning basis.

For the first time, the broad coverage provides simultaneous study of thermal components, non-thermal components, iron lines, and reflection features from a single platform for accreting black holes at all scales. The enormous collecting area allows detailed studies of the dense matter equation of state using both thermal emission from rotation-powered pulsars and harder emission from X-ray burst oscillations. The combination of the wide-field monitor and the sensitive pointed instruments enables observations of potential electromagnetic counterparts to LIGO and neutrino events. Additional extragalactic science, such as high quality spectroscopy of clusters of galaxies and unprecedented timing investigations of active galactic nuclei, is also obtained.

Author(s): Colleen A. Wilson-Hodge[4], Paul S. Ray[6], Keith Gendreau[3], Deepto Chakrabarty[2], Marco Feroci[1], Thomas J. Maccarone[8], Zaven Arzoumanian[3], Ronald A. Remillard[2], Kent Wood[7], Christopher Griffith[5], Peter Jenke[9]
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103.25 – HaloSat – A CubeSat to Study the Hot Galactic Halo

Observations of the nearby universe fail to locate about half of the normal matter (baryons) observed in the early universe. The missing baryons may be in hot galactic halos. HaloSat is a CubeSat designed to map oxygen line emission (O VII and O VIII) around the Milky Way in order to constrain the mass and spatial distribution of hot gas in the halo. HaloSat has a grasp competitive with current X-ray observatories. Its observing program will be optimized to minimize contributions from solar wind charge exchange (SWCX) emission that limit the accuracy of current measurements. We describe the current status of HaloSat.

Author(s): Philip Kaaret[1]
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103.26 – Overview of the SVOM Gamma-Ray Burst mission under development with a focus on its Trigger system

The SVOM mission (Space-based Variable Objects Monitor) is a Chinese-French satellite mission under development, devoted to collecting a complete sample of Gamma-Ray Bursts (GRBs) observed at multi-wavelengths with a high fraction of redshift determinations. In January 2017 the mission entered Phase C, starting officially construction, and the launch is foreseen in 2021. The SVOM satellite is equipped with 4 instruments, 2 of which cover the prompt GRB phase. The ECLAIRs coded-mask imager surveys a 2-sr large portion of the sky in the 4-150 keV energy range, well

suited for the detection of X-ray rich and highly redshifted GRBs. The ECLAIRs trigger system continuously searches for GRBs using two algorithms, a count-rate trigger for short time scales and an image trigger for long time scales. In case of a localized new GRB candidate or a bright outburst of a known source, it promptly requests a satellite slew and sends an alert to ground. The onboard GRM (Gamma-Ray Monitor) extends the prompt energy coverage up to 5 MeV. After slew, 2 more onboard instruments study the GRB afterglow and refine the GRB localization: the MXT (Multi-pore optics X-ray Telescope) and the VT (Visible Telescope). Two types of ground telescopes are dedicated to SVOM. The GFTs (Ground Follow-up Telescopes) repoint autonomously to GRB alerts, refine their localization and provide photometric redshift. The SVOM observing strategy with roughly antisolar pointing combined with Galactic plane avoidance, ensures that most GRBs are quickly visible by the GFTs and large spectroscopic telescopes. The GWAC (Ground Wide Angle Camera) will observe the sky simultaneously with ECLAIRs to detect prompt optical GRB emissions. Today part of the GWAC is already operational. The SVOM GRB program is complemented by pre-planned target observations and ground-commanded targets of opportunity, e.g. to search for electromagnetic counterparts of gravity-wave events. On behalf of the SVOM and ECLAIRs teams, this paper presents an overview of SVOM with a focus on its GRB trigger system.
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103.27 – Carbon Fiber Mirror for a CubeSat Telescope

Telescope mirrors made by carbon fibers have been increasingly used especially for space applications, and they may replace the traditional glass mirrors. Glass mirrors are easy to fabricate, but needed to be carefully handled as they are brittle. Other materials have also been considered for telescope mirrors, such as metals, plastics, and liquids even. However glass and glass ceramics are still commonly and dominantly used.
Carbon fiber has mainly been used for mechanical supports like truss structure and telescope tubes, as it is stiff and light-weight. It can also be a good material for telescope mirrors, as it has additional merits of non-brittle and very low thermal expansion. Therefore, carbon fiber mirror would be suitable for space telescopes which should endure the harsh vibration conditions during launch.
A light-weight telescope made by carbon fiber has been designed for a small satellite which would have much less weight than conventional ones. In this poster, mirror materials are reviewed, and a design of carbon fiber telescope is presented and discussed.
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Institution(s): *1. Korea Astronomy and Space Science Institute*

103.28 – High Resolution Energetic X-ray Imager (HREXI) for a Prototype 12U CubeSat

Our High Resolution Energetic X-ray Imager (HREXI) program is developing an Engineering Model (EM) for a 12U CubeSat wide-field hard X-ray (3-200 keV) coded-aperture imaging telescope. HREXI employs an array of CdZnTe (CZT) detectors (each 2 x 2 x 0.3 cm) with a fine-pixellated Tungsten coded aperture mask. The detector assembly utilizes the new technology of Through-Silicon-Vias (TSVs) to control and readout signals from the ASIC bonded to each CZT. TSVs eliminate the need for conventional wire-bonds for electric connections between the ASIC and back end electronics, greatly lowering the assembly complexity and cost, and thus enabling close-tiling of HREXI detectors in a small form factor with comfortable margins. For HREXI EM, we have successfully implemented TSVs on NuSTAR ASICs, which can cover an energy range of 3-200 keV with a FWHM spectral resolution of 1-2 keV. The 12U CubeSat HREXI EM prototype with 64 CZT detectors would image 0.5 sr of sky with FWHM field of view with 11 arcmin resolution for the current generation of the TSV-ASIC and a 20 cm mask - detector plane separation. A flight test of this 12U-HREXI will be proposed after full development and environmental testing to enable a future proposed array of SmallSat-HREXI telescopes with ~2 arcmin resolution for simultaneous full-sky studies of high redshift GRBs and a wide range of transients in the post-Swift era. (This work is supported by NASA grant NNX17AE62G)
Author(s): JaeSub Hong[3], Branden Allen[3], Jonathan E. Grindlay[3], Scott Douglas Barthelmy[2], Fiona Harrison[1]
Institution(s): *1. Caltech, 2. GSFC, 3. Harvard Univ.*

103.29 – The Advanced Telescope for High Energy Astrophysics

Athena (the Advanced Telescope for High Energy Astrophysics) is a next generation X-ray observatory currently under study by ESA for launch in 2028. Athena is designed to address the Hot and Energetic Universe science theme, which addresses two key questions: 1) How did ordinary matter evolve into the large scale structures we see today? 2) How do black holes grow and shape the Universe. To address these topics Athena employs an innovative X-ray telescope based on Silicon Pore Optics technology to deliver extremely light weight and high throughput, while retaining excellent angular resolution. The mirror can be adjusted to focus onto one of two focal place instruments: the X-ray Integral Field Unit (X-IFU) which provides spatially-resolved, high resolution spectroscopy, and the Wide Field Imager (WFI) which provides spectral imaging over a large field of view, as well as high time resolution and count rate tolerance. Athena is currently in Phase A and the study status will be reviewed, along with the scientific motivations behind the mission.
Author(s): Matteo Guainazzi[1]
Institution(s): *1. European Space Agency, ESTEC*

104 – First Results from NICER: X-ray Astrophysics from the International Space Station Poster Session

104.01 – Searching for X-ray Pulsations from Neutron Stars Using NICER

The Neutron Star Interior Composition Explorer (NICER) presents an exciting new capability for discovering new modulation properties of X-ray emitting neutron stars, including large area, low background, extremely precise absolute time stamps, superb low-energy response and flexible scheduling. The Pulsation Searches and Multiwavelength Coordination working group has designed a 2.5 Ms observing program to search for pulsations and characterize the modulation properties of about 30 known or suspected neutron star sources across a number of source categories. A key early goal will be to search for pulsations from millisecond pulsars that might exhibit thermal pulsations from the surface suitable for pulse profile modeling to constrain the neutron star equation of state. In addition, we will search for pulsations from transitional millisecond pulsars, isolated neutron stars, LMXBs, accretion-powered millisecond pulsars, central compact objects and other sources. We will present our science plan and initial results from the first months of the NICER mission.

Author(s): Paul S. Ray[7], Zaven Arzoumanian[5], Slavko Bogdanov[1], Peter Bult[5], Deepto Chakrabarty[4], Sebastien Guillot[8], Alice Kust Harding[5], Wynn C. G. Ho[9], Frederick K. Lamb[2], Simin Mahmoodifar[5], M. Coleman Miller[3], Tod E. Strohmayer[5], Colleen A. Wilson-Hodge[6], Michael Thomas Wolff[7]
Institution(s): *1. Columbia University, 2. Illinois, 3. Maryland, 4. MIT, 5. NASA/GSFC, 6. NASA/MSFC, 7. NRL, 8. Pontificia Universidad Católica de Chile, 9. Southampton*

104.02 – Estimating the masses and radii of neutron stars using NICER pulse waveform data

The key scientific objective of the Neutron Star Interior Composition Explorer (*NICER*) is to precisely and reliably measure the mass M and radius R of several neutron stars, in order to tightly constrain the properties of cold ultradense matter. M and R will be measured by fitting energy-dependent pulse waveform models to the observed soft X-ray pulse waveforms of selected rotation-powered millisecond pulsars. These waveforms are thought to be produced by rotation with the stellar surface of hot spots located near the pulsar's magnetic polar caps. We have explored the accuracies and precisions with which *NICER* should be able to determine M and R, by analyzing synthetic waveform data using Bayesian statistical methods. Here we describe the pulse waveform models that will be used by the *NICER* mission, the scaling of the uncertainties in M and R estimates with the total number of counts, and the dependence of the uncertainties in M and R estimates on the rotational colatitudes of the hot spots and the inclination of the observer. We show that the shapes of the hot spots and modest variations in the temperature of the emission across them are unlikely to produce significant systematic errors. We find that *NICER* should be able to measure the masses and radii of a few neutron stars to within 5%.

Author(s): Frederick K. Lamb[1], M. Coleman Miller[2]
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104.03 – Expected constraints on the masses and radii of J0437-4715 and J0030+0451 using NICER data

An important goal of the Neutron Star Interior Composition Explorer (NICER) is to precisely and reliably measure the mass M and radius R of selected neutron stars, to constrain the properties of cold matter at supranuclear densities. As the poster to the left describes, NICER will measure M and R by fitting pulse waveform models to the observed soft X-ray pulse waveforms of several rotation-powered millisecond pulsars. These waveforms are thought to be produced by the rotation of hot spots located near the pulsar's magnetic polar caps. Key NICER targets are the 174-Hz pulsar PSR J0437-4715 and the 205-Hz pulsar PSR J0030+0451. We have explored the accuracies and precisions with which NICER should be able to determine the masses and radii of these pulsars, by analyzing synthetic waveform data using Bayesian statistical methods. Using the current knowledge of the mass and distance of PSR J0437-4715 as priors, we find that NICER should be able to measure the mass of this pulsar to within 6% (1 sigma) and its radius to within 4% by combining observations lasting a total of 1 Ms. Other properties of this pulsar, such as the colatitudes and azimuthal separation of its hot spots, can also be measured fairly precisely by fitting its pulse waveform. We find that by combining observations lasting 3 Ms, NICER should be able to measure the mass of PSR J0030+0451 to within 9% and its radius to within 6%, if the spot colatitudes and the observer's inclination are not known independently of the pulse waveform analysis, or to within 5% and 3%, respectively, if these angles are independently known.

Author(s): M. Coleman Miller[1], Frederick K. Lamb[2]
Institution(s): *1. Univ. of Maryland, 2. University of Illinois*

104.04 – Neutron Star Dense Matter Equation of State Constraints with NICER

One of the principal goals of the Neutron Star Interior Composition Explorer (NICER) is to place constraints on the dense matter equation of state through sensitive X-ray observations of neutron stars. The NICER mission will focus on measuring the masses and radii of several relatively bright, thermally-emitting, rotation-powered millisecond pulsars, by fitting models that incorporate all relevant relativistic effects and atmospheric radiation transfer processes to their periodic soft X-ray modulations. Here, we provide an overview of the targets NICER will observe and tthe technique and models that have been developed by the NICER team to estimate the masses and radii of these pulsars.

Author(s): Slavko Bogdanov[1], Zaven Arzoumanian[3], Deepto Chakrabarty[2], Sebastien Guillot[5], Alice Kust Harding[3], Wynn C. G. Ho[11], Frederick K. Lamb[9], Simin Mahmoodifar[3], M. Coleman Miller[10], Sharon Morsink[6], Feryal Ozel[8], Dimitrios Psaltis[8], Paul S. Ray[4], Tom Riley[7], Tod E. Strohmayer[3], Anna Watts[7], Michael Thomas Wolff[4],Keith Gendreau[3]
Institution(s): *1. Columbia University, 2. MIT, 3. NASA/GSFC, 4. NRL, 5. Pontificia Universidad Catolica de Chile, 6. University of Alberta, 7. University of Amsterdam, 8. University of Arizona, 9. University of Illinois, 10. University of Maryland, 11. University of Southampton*

104.05 – Burst Oscillation Studies with *NICER*

Type I X-ray bursts are thermonuclear flashes observed from the surfaces of accreting neutron stars in Low Mass X-ray Binaries. Oscillations have been observed during the rise and/or decay of some of these X-ray bursts. Those seen during the rise can be well explained by a spreading hot spot model, but large amplitude oscillations in the decay phase remain mysterious because of the absence of a clear-cut source of asymmetry. Here we present the results of our computations of the light curves and amplitudes of oscillations in X-ray burst models that realistically account for both flame spreading and subsequent cooling. For the cooling phase of the burst we use two simple phenomenological models. The first considers asymmetric cooling that can achieve high amplitudes in the tail. The second considers a sustained temperature pattern on the stellar surface that is produced by r-modes propagating in the surface fluid ocean of the star. We will present some simulated burst light curves/spectra using these models and *NICER* response files, and will show the capabilities of *NICER* to detect and study burst oscillations. *NICER* will enable us to study burst oscillations in the energy band below ~3 keV, where there has been no previous measurements of these phenomena.

Author(s): Simin Mahmoodifar[1], Tod E. Strohmayer[1]
Institution(s): *1. NASA/GSFC*

104.06 – Orbitally-Modulated High Energy Emission from Millisecond Pulsar Binaries

Radio, optical and X-ray followup of unidentified Fermi sources has expanded the number of known galactic-field "black widow" and "redback" millisecond pulsar binaries from four to nearly 30. Several systems observed by Chandra, XMM, Suzaku, and NuSTAR exhibit double-peaked X-ray orbital modulation. This is attributed to synchrotron emission from electrons accelerated in an intrabinary shock and Doppler boosting by mildly relativistic bulk flow along the shock. It is anticipated that NICER will also detect such emission from B1957+20 and other targets. The structure of the orbital X-ray light curves depend upon the binary inclination, shock geometry, and particle acceleration distribution. In particular, the spatial variation along the shock of the underlying electron power-law index yields energy-dependence in the shape of light curves motivating future high energy phase-resolved spectroscopic studies to probe the unknown physics of pulsar winds and relativistic shock acceleration therein. We also briefly discuss stability of the shock to dynamical perturbations for redbacks and how observations of correlated X ray-optical variability may test self-regulatory stabilizing mechanisms.

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

104.07 – Observations of Black Hole Binaries with NICER

The Neutron Star Interior Composition Explorer (NICER; to be launched 2017 June) will observe persistent Black Hole (BH) Binaries and BH-type transients during its 18-month Prime Mission. Substantial advances are expected from investigations of BH physical properties and accretion physics in strong gravity, continuing the science legacy of RXTE. One of the primary differences between NICER/XTI and RXTE/PCA Instruments is the energy response (0.2-12 keV vs 3-45 keV). NICER provides a direct spectral view of the inner accretion disk, where the maximum effective temperatures vary in the range 0.2-2 keV. In addition, NICER provides superior spectral resolution (140 eV at Fe K-alpha), superior time resolution (100 ns absolute accuracy), lower background (by a factor of 100), and full flexibility for data analyses (with complete information for every photon event). Finally the source count rate from NICER's 56 cameras will exceed the rate from RXTE (3 PCUs), except for sources obscured by very high levels of ISM column density (log Nh > 22).
Anticipated BH science themes include sensitive measures of the effective radius and temperature of the inner disk during BH hard states and transitions, full use the disk spectrum (as seed photons) for Comptonization models for the corona, and powerful opportunities to interpret timing properties including QPOs. Such capabilities will support a new initiative on the "disk:corona" connection, which is a fundamental component of the "disk:jet" connection and our understanding of the different accretion states. Early results from NICER will be reported, to the extent possible.

Author(s): Ronald A. Remillard[1], Edward Cackett[4], Andrew C Fabian[2], Jon M. Miller[3], Deeraj Ranga Reddy Pasham[1], James F. Steiner[1]

Institution(s): *1. MIT, 2. U Cambridge, 3. U Michigan, 4. Wayne State U*

104.08 – NICER Observations of Serpens X-1

Relativistic emission lines from the inner disk can be used to set an upper limit on the radius of accreting neutron stars. Serpens X-1 is a neutron star X-ray binary wherein a strong, skewed Fe K emission line and broadband disk reflection spectrum have been observed. The ability of NICER to observe bright sources and to extend spectra down to 0.2 keV means that relativistic lines from low-Z elements may become readily accessible in sources like Serpens X-1, potentially leading to tighter constraints on neutron star radii. Here, we report on early observations of Serpens X-1 with NICER, with specific attention to the low energy spectrum, disk reflection, and derived radii.

Author(s): Jon M. Miller[1]
Institution(s): *1. Univ. of Michigan*

104.09 – AMXP Pulse variability wih NICER

Accreting millisecond X-ray pulsars show a diverse scope variability, including coherent pulsations from the stellar surface and quasi-periodic oscillations attributed to the accretion flow. Because the pulsations are ultimately powered by accreting material, it may be expected that these periodic and quasi-periodic signals show coupled behavior. Observing and characterizing such coupling then gives a unique view of the flow of matter in the closest vicinity of the neutron star surface. In this contribution I will present recently developed specialized methods that can detect such coupling, and discuss how high quality X-ray observations by NICER may enable pulse amplitude modulation studies, and their potential to constrain the physics of accretion.

Author(s): Peter Bult[1]
Institution(s): *1. NASA/GSFC*

104.10 – Calibration of NICER detectors at the synchrotron radiation facility BESSY-II

The focal plane of the NICER instrument includes 56 nearly identical Silicon Drift Detectors.
Two Silicon Drift Detectors from the flight candidates lot were selected for calibration at a synchrotron. One of those two calibrated detectors was later installed into the flight instrument focal plane.
The calibration was performed at BESSY-II electron storage ring in Berlin and consisted of detector characterization at several beam lines, where each measurement served different purpose. Low energy QE was measured by comparing the detected X-ray flux against calibrated photodiode using SX700 grating monochromator beam line. Detector response function was evaluated at multiple monochromatic energies using Four Crystal Monochromator (FCM) beam line. In addition to that, the detector QE in a wide energy range was measured by illuminating detector by undispersed synchrotron X-ray radiation at extremely low (just a few electrons) ring currents.

Here we present the results of the measurements, and discuss some unexpected features of the detector performance discovered in the course of this testing. Overall, BESSY calibration turned out to be an extremely powerful tool for studying detector performance across entire X-ray range of interest for NICER.

Author(s): Gregory Prigozhin[2], James F. Steiner[2], Andrew Malonis[2], John Doty[3], Beverly LaMarr[2], Ronald A. Remillard[2], Frank Scholze[4], Christian Laubis[4], Michael Krumrey[4], Keith Gendreau[1]
Institution(s): *1. GSFC NASA, 2. Massachusetts Institute of Technology, 3. Noqsi Aerospace, 4. PTB*

105 – Galaxy Clusters and Cosmology Poster Session

105.01 – Deep X-ray Observations of an Ongoing Merger and 400 Myr of AGN Activity in Cygnus A

We present a detailed spatial and spectral analysis of the large-scale X-ray emission associated with the merging cluster of galaxies containing the powerful Cygnus A radio galaxy. Using a new 1 Msec exposure from the ongoing Chandra XVP project, we have mapped the large-scale structure, temperature and abundance of the ICM in a 1 Mpc x 1 Mpc region surrounding Cygnus A. This new, deep exposure resolves unprecedented detail in the jets, lobes, and cocoon shock associated with Cygnus A, and provides new insights into the emission mechanisms that produce these features as well as implications for the ongoing activity of the central AGN. On larger scales, these new data reveal complex and dramatic temperature, pressure, entropy and metallicity structure in the ICM surrounding Cygnus A. We confirm the presence of large-scale X-ray emission associated with the two merging cluster components seen previously in lower resolution data. The temperature structure on the scale of the merger exhibits an asymmetric enhancement to the NW consistent with projected hotter gas from the merger shock. Using the derived density and temperature profiles in the two merging sub-cluster components as inputs, we have constructed a grid of hydro-dynamical simulations to constrain the geometry of the merger system. These models imply a pre-merger system with a 1:1 mass ratio at the virial radius with an inclination toward the line of sight of 35-45 deg. In addition to the merger-induced temperature asymmetry, we find evidence for additional surface brightness and temperature features indicative of previous outburst activity in Cygnus A over the past 400 Myr. Based on the location and strength of these features, we derive the energy associated with these previous outbursts and place constraints on the growth of the black hole in Cygnus A over that timescale.

Author(s): Michael W Wise[1], Martijn De Vries[4], Paul Nulsen[3], Bradford Snios[3], Mark Birkinshaw[5], Diana Worrall[5], Ryan Duffy[5], Timo Halbesma[4], Julius Donnert[2], Martin Hardcastle[6]
Institution(s): *1. ASTRON (Netherlands Institute for Radio Astronomy), 2. Leiden University, 3. SAO, 4. University of Amsterdam, 5. University of Bristol, 6. University of Hertfordshire*

105.02 – An abundance of phenomena: mergers, AGN feedback, radio galaxies, sloshing, and filaments in the NGC 741 group

While AGN and mergers are thought to play important roles in group and cluster evolution, their effects in galaxy groups are poorly understood. We show recent results from an analysis of deep Chandra and XMM-Newton observations of NGC 741, which provides an excellent example of a group with multiple concurrent phenomena: both an old central radio galaxy and a spectacular infalling head-tail source, strongly-bent jets, a 100kpc radio trail, intriguing narrow X-ray filaments, and gas sloshing features. Supported principally by X-ray and radio continuum data, we address the merging history of the group, the nature of the X-ray filaments, the extent of gas stripping from NGC 742, the character of cavities in the group, and the roles of the central AGN and infalling galaxy in heating the intra-group medium.

Author(s): Jan M. Vrtilek[1], Gerrit Schellenberger[1], Laurence P. David[1], Ewan O'Sullivan[1], Simona Giacintucci[3], Melanie Johnston-Hollitt[4], Stefan Duchesne[4], Somak Raychaudhury[2]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. IUCAA, 3. Naval Research Laboratory, 4. Victoria University*

105.04 – Is there a giant Kelvin-Helmholtz instability in the sloshing cold front of the Perseus cluster?

Deep observations of nearby galaxy clusters with Chandra have revealed concave 'bay' structures in a number of systems (Perseus, Centaurus and Abell 1795), which have similar X-ray and radio properties. These bays have all the properties of cold fronts, where the temperature rises and density falls sharply, but are concave rather than convex. By comparing to simulations of gas sloshing, we find that the bay in the Perseus cluster bears a striking resemblance in its size, location and thermal structure, to a giant (≈50 kpc) roll resulting from Kelvin-Helmholtz instabilities. If true, the morphology of this structure can be compared to simulations to put constraints on the initial average ratio of the thermal and magnetic pressure, $\beta= p_{th}/ p_B$, throughout the overall cluster before the sloshing occurs, for which we find β=200 to best match the observations. Simulations with a stronger magnetic field (β=100) are disfavoured, as in these the large Kelvin-Helmholtz rolls do not form, while in simulations with a lower magnetic field (β=500) the level of instabilities is much larger than is observed. We find that the bay structures in Centaurus and Abell 1795 may also be explained by such features of gas sloshing.

Author(s): Stephen Walker[3], Julie Hlavacek-Larrondo[4], Marie-Lou Gendron-Marsolais[4], Andrew C Fabian[5], Huib Intema[1], Jeremy Sanders[2]
Institution(s): *1. Leiden Observatory, 2. Max-Planck-Institute fur extraterrestrische Physik, 3. NASA Goddard Space Flight Center, 4. Universite de Montreal, 5. University of Cambridge*

105.05 – X-Ray Properties of Lensing-Selected Clusters

I will present preliminary results from the Michigan *Swift* X-ray observations of clusters from the Sloan Giant Arcs Survey (SGAS). These clusters were lensing selected based on the presence of a giant arc visible from SDSS. I will characterize the morphology of the intracluster medium (ICM) of the clusters in the sample, and discuss the offset between the X-ray centroid, the mass centroid as determined by strong lensing analysis, and the BCG position. I will also present early-stage work on the scaling relation between the lensing mass and the X-ray luminosity.

Author(s): Rachel Paterno-Mahler[5], Keren Sharon[5], Matthew Bayliss[1], Michael McDonald[1], Michael Gladders[3], Traci Johnson[5], Hakon Dahle[6], Jane R. Rigby[2], Katherine E. Whitaker[4], Michael Florian[3], Eva Wuyts[3]
Institution(s): *1. MIT, 2. NASA/Goddard, 3. University of Chicago, 4. University of Connecticut, 5. University of Michigan, 6. University of Oslo*

105.06 – Jets and a cold chaotic disk in the central pc of the Perseus cluster

We detect a new jet at the center of NGC 1275 in the Perseus cluster with Very Long Baseline Array at 15 and 43 GHz. The jet is found north of the central Active galactic nucleus (AGN) and the size is ~2 mas (~0.8 pc). It seems to be the counterjet of a known radio jet expanding to the south. From the ratio of the lengths of the two jets, the inclination angle of the jet is estimated to be about 65 degs. The large angle can strongly constrain gamma-ray emission mechanism from the AGN. Contrary to the south jet, the new north jet is strongly absorbed, which suggests that the AGN is surround by a parsec-scale cold disk with the density of $\geq 10^5$ cm^{-3}. The spectrum of the north jets indicates that the disk is highly inhomogeneous. Our results supports the idea that gas accretes on the AGN at the center of a cluster via a cold chaotic disk.

Author(s): Yutaka Fujita[2], Hiroshi Nagai[1]

Institution(s): *1. National Astronomical Observatory of Japan, 2. Osaka Univ.*

105.07 – High-dynamic range JVLA observations of clusters of galaxies

The recently upgraded JVLA has enabled a breakthrough in radio astronomy by providing a radio telescope with unprecedented sensitivity, resolution, and imaging capabilities. We present new JVLA observations of clusters of galaxies, including state-of-the-art low-frequency 230-470 MHz observations of the Perseus cluster. These observations not only illustrate the high-quality/high-dynamic range images that can be obtained with the upgraded JVLA, but they also reveal that mini-halos are not simply diffuse, uniform radio sources. Instead, mini-halos appear to be filled with a rich variety of complex radio structures including arcs, filaments and edges. The depth and resolution of the JVLA observations allow us to conduct for the first time a detailed comparison of the mini-halo structure with the X-ray structure as seen in the Chandra X-ray images, providing new clues about the acceleration mechanisms of relativistic particles in the intracluster medium.

Author(s): Julie Hlavacek-Larrondo[1]
Institution(s): *1. Université de Montréal*

105.08 – The Cocoon Shock of Cygnus A

Cygnus A is an archetype FRII radio galaxy and is the nearest powerful radio galaxy in the Universe. It is hosted by the central galaxy of a rich cluster, and X-ray observations of the system provide a unique opportunity to investigate the physical structure of a powerful radio galaxy as well as the galaxy's impact on the cluster host. My talk will cover our analysis of the recent deep exposure *Chandra* observations of Cygnus A's cocoon shock. The observational data is fitted with multiple models to assess the speed and strength of the cocoon shock to high accuracy. The results show that the shocked gas is driven with a generally uniform pressure, although a pressure difference of 30% is seen between the radio lobes. I will discuss implications of these findings on both the radio jet properties and the jet's interactions with its cluster atmosphere.

Author(s): Bradford Snios[2], Ralph P. Kraft[2], Paul Nulsen[2], Michael W Wise[1]
Institution(s): *1. ASTRON, 2. SAO*

105.09 – The Hydrodynamics of Galaxy Transformation in Extreme Cluster Environments

Cluster of galaxies are hostile environments. Infalling cluster galaxies are stripped of their dark matter, stars, and hot and cold interstellar medium gas. The ISM, in addition to tidal and ram pressure stripping, can evaporate due to thermal conduction. Gas loss and the subsequent suppression of star formation is not straightforward: magnetic fields in the ISM and ICM shield galaxies and their stripped tails from shear instabilities and conduction, radiative cooling can inhibit gas loss, and feedback from stars and AGN can replenish the ISM. While there is observational evidence that these processes operate, a theoretical understanding of the physics controlling the energy cycle in cluster galaxies remains elusive. Additionally, galaxies have a significant impact on ICM evolution: orbiting galaxies stir up and stretch ICM magnetic field lines, inject turbulence into the ICM via their wakes and g-waves, and infuse metals into the ICM. Quantifying the balance between processes that remove, retain, and replenish the ISM, and the impact of galaxies on the ICM require specialized hydrodynamic simulations of the cluster environment and its galaxies. I will present results from some of these simulations that include ram pressure stripping of galaxies' hot ISM, the effect of magnetic fields on this process, and the effectiveness of isotropic and anisotropic thermal conduction in removing and retaining the ISM. I will also quantify magnetic field amplification and turbulence injection due to orbiting galaxies, and implications for X-ray and radio observations and measurements of galactic coronae, tails, magnetic fields, and turbulence.

Author(s): Rukmani Vijayaraghavan[1]
Institution(s): *1. University of Virginia*

105.10 – Galaxy clusters as hydrodynamics laboratories

The intra-cluster medium (ICM) of galaxy clusters shows a wealth of hydrodynamical features that trace the growth of clusters via the infall of galaxies or smaller subclusters. Such hydrodynamical features include the wakes of the infalling objects as well as the interfaces between the host cluster's ICM and the atmosphere of the infalling object. Furthermore, the cluster dynamics can be traced by merger shocks, bow shocks, and sloshing motions of the ICM.

The characteristics of these dynamical features, e.g., the direction, length, brightness, and temperature of the galaxies' or subclusters' gas tails varies significantly between different objects. This could be due to either dynamical conditions or ICM transport coefficients such as viscosity and thermal conductivity. For example, the cool long gas tails of of some infalling galaxies and groups have been attributed to a substantial ICM viscosity suppressing mixing of the stripped galaxy or group gas with the hotter ambient ICM.

Using hydrodynamical simulations of minor mergers we show, however, that these features can be explained naturally by the dynamical conditions of each particular galaxy or group infall. Specifically, we identify observable features to distinguish the first and second infall of a galaxy or group into its host cluster as well as characteristics during apocentre passage. Comparing our simulations with observations, we can explain several puzzling observations such as the long and cold tail of M86 in Virgo and the very long and tangentially oriented tail of the group LEDA 87445 in Hydra A.

Using our simulations, we also assess the validity of the stagnation pressure method that is widely used to determine an infalling galaxy's velocity. We show that near pericentre passage the method gives reasonable results, but near apocentre it is not easily applicable.

Author(s): Elke Roediger[1], Alexander Sheardown[1], Thomas Fish[1], John ZuHone[2], Matthew Hunt[1], Yuanyuan Su[2], Ralph P. Kraft[2], Paul Nulsen[2], William R. Forman[2], Eugene Churazov[3], Scott W. Randall[2], Christine Jones[2], Marie E. Machacek[2]
Institution(s): *1. E.A. Milne Centre for Astrophysics, University of Hull, 2. Harvard-Smithsonian Center for Astrophysics, 3. MPA*

105.11 – Electron Heating and Acceleration at Galaxy Cluster Shocks: Insights from *NuSTAR*

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. Recent observations of the massive merging clusters Abell 2163, Abell 665, and the Bullet cluster with *NuSTAR*, the first focusing hard (>10 keV) X-ray observatory, improve measurements of both thermal and IC components in each cluster. In the Bullet Cluster, we jointly fit long *Chandra* and *NuSTAR* observations--totaling 1 Ms--to constrain the temperature of the bow shock and determine whether electrons are directly heated by the shock front as previously suggested by Chandra data alone. We also preview *NuSTAR* constraints on the temperature of the recently discovered shock in Abell 665 and on the flux of IC emission from the electrons producing radio halos in all three clusters.

Author(s): Daniel R. Wik[6], Silvano Molendi[2], Allan Hornstrup[1], Fabio Gastaldello[2], Greg Madejski[4], Niels J Westergaard[1], Sarthak Dasadia[5], Craig L. Sarazin[7], Ming Sun[5],Maxim L. Markevitch[3]
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105.12 – Closed Box Nature of Galaxy Clusters through Multi-wavelength Analysis

Relating observations of cluster galaxies or the gas content to the total mass of the underlying dark matter halos is a key challenge in the current cluster cosmology community. On the other hand, accurate measurement of hot and cold phase baryon covariance in clusters will offer important constraints on hydrodynamic models of cluster formation. This property covariance has been predicted by hydrodynamics simulations of Wu et al. (2015). Wu et al. (2015) predicts massive dark-matter halos are essentially ``Closed Box'' that retain all their gaseous and stellar matter, despite a diverse set of astrophysical disruptions happening inside them.

We build a forward Bayesian model to constrain the mass observable scaling relation and test ``Closed Box'' scenario through the property covariance, simultanously. We, then, present results of this method applied to multi-wavelength observations of clusters from the Local Cluster Substructure Survey (LoCuSS). We find ~3σ evidence that at least one of the covariances between hot gaseous probes and stellar mass probes is negative. These results provide the first observational evidence in favor of the ``Closed Box'' nature of clusters at the high mass end.

Author(s): Arya Farahi[2], Sarah Mulroy[1], August E. Evrard[2], Graham Smith[1]
Institution(s): *1. University of Birmingham, 2. University of Michigan*

105.13 – Suppression of AGN-Driven G-Mode Turbulence by Magnetic Fields in a Magnetohydrodynamic Model of the Intracluster Medium

We investigate the role of AGN feedback in turbulent heating of galaxy clusters. X-ray measurements of the Perseus Cluster intracluster medium (ICM) by the Hitomi Mission found a velocity dispersion measure of $\sigma \sim 164$ km/s, indicating a large-scale turbulent energy of approximately 4% of the thermal energy. If this energy is transferred to small scales via a turbulent cascade and dissipated as heat, radiative cooling can be offset and the cluster can remain in the observed thermal equilibrium. Using 3D ideal MHD simulations and a plane-parallel model of the ICM, we analyze the production of turbulence by g-modes generated by the supersonic expansion and buoyant rise of AGN-driven bubbles. Previous work has shown that this process is inefficient, with less than 1% of the injected energy ending up in turbulence. Hydrodynamic instabilities shred the bubbles apart before they can excite sufficiently strong g-modes. We examine the role of a large-scale magnetic field which is able to drape around these rising bubbles, preserving them from instabilities. We show that a helical magnetic field geometry is able to better preserve bubbles, driving stronger g-modes; however, the production of turbulence is still inefficient. Magnetic tension acts to stabilize g-modes, preventing the nonlinear transition to turbulence. In addition, the magnetic tension force acts along the field lines to suppress the formation of small-scale vortices. These two effects halt the turbulent cascade. Our work shows that ideal MHD is an insufficient description for the cluster feedback process, and we discuss future work such as the inclusion of anisotropic viscosity as a means of simulating high β plasma kinetic effects. In addition, other mechanisms of heating the ICM plasma such as sound waves or cosmic rays may be responsible to account for observed feedback in galaxy clusters.

Author(s): Christopher J Bambic[1], Brian J Morsony[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland, College Park*

105.14 – What Do the *Hitomi* Observations Tell Us About the Turbulent Velocities in the Perseus Cluster?

Recently, the *Hitomi* X-ray Observatory provided the first-ever direct measurements of Doppler line shifting and broadening from the hot plasma in clusters of galaxies via its observations of the Perseus Cluster. It has been reported that these observations demonstrate that the ICM in Perseus is "quiescent". It is indisputable that the velocities inferred from the measured line shifts and broadening are low, but what do these observations imply about the structure of the velocity field on scales smaller than the *Hitomi* PSF? We use hydrodynamic simulations of gas motions in a cool-core cluster in combination with synthetic *Hitomi* observations in order to compare the observed line-of-sight velocities to the 3D velocity structure of the ICM, and assess the impact of *Hitomi's* spatial resolution and the effects of varying the underlying ICM physics.

Author(s): John A. ZuHone[1], Eric D. Miller[2], Esra Bulbul[2], Irina Zhuravleva[3]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Massachusetts Institute of Technology, 3. Stanford University*

105.15 – The Complete Local-Volume Groups Sample (CLoGS): Early results from X-ray and radio observations

Although the group environment is the dominant locus of galaxy evolution (in contrast to rich clusters, which contain only a few percent of galaxies), there has been a lack of reliable, representative group samples in the local Universe. In particular, X-ray selected samples are strongly biased in favor of the X-ray bright, centrally-concentrated cool-core systems. In response, we have designed the Complete Local-Volume Groups Sample (CLoGS), an optically-selected statistically-complete sample of 53 groups within 80 Mpc which is intended to overcome the limitations of X-ray selected samples and serve as a representative survey of groups in the local Universe. We have supplemented X-ray data from Chandra and XMM (70% complete to date, using both archival and new observations, with a 26-group high richness subsample 100% complete) with GMRT radio continuum observations (at 235 and 610 MHz, complete for the entire sample). CLoGS includes groups with a wide variety of properties in terms of galaxy population, hot gas content, and AGN power. We here describe early results from the survey, including the range of AGN activity observed in the dominant galaxies, the relative fraction of cool-core and non-cool-core groups in our sample, and the degree of disturbance observed in the IGM.

Author(s): Jan M. Vrtilek[1], Ewan O'Sullivan[1], Laurence P. David[1], Simona Giacintucci[3], Konstantinos Kolokythas[2]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. IUCAA, 3. Naval Research Laboratory*

105.16 – Probing the Supernova Fraction out to the Virial Radius of A3112

Owing to their deep potential wells, clusters of galaxies retain all metals synthesized by supernova explosions. The low particle background of Suzaku detectors has allowed the measurements of the chemical enrichment in faint cluster outskirts. I will present our recent Suzaku measurements of the type Ia to core collapse supernova fraction out to the viral radius of a nearby cluster A3112. The observed uniform distribution at a level of 12-16% is consistent with the supernova fraction in our Galaxy. The non-varying supernova fraction indicates that the intra-cluster medium in cluster outskirts was enriched by metals at an early star formation stage at redshifts of 2-3.

Author(s): Esra Bulbul[2], Mark W. Bautz[2], Eric D. Miller[2], Cemile Ezer[1], Nihal Ercan[1], Randall K. Smith[4], Michael Loewenstein[3], Michael McDonald[2]
Institution(s): *1. Bogazici Univ., 2. MIT, 3. NASA/GSFC, 4. SAO*

105.17 – Anatomy of a Merger: A Deep Chandra Observation of Abell 115

A deep Chandra observation of Abell 115 provides a unique probe of the anatomy of cluster mergers. The X-ray image shows two prominent subclusters, A115N (north) and A115S (south) with a projected separation of almost 1 Mpc. The X-ray subclusters each have ram-pressure stripped tails that unambiguously indicate the directions of motion. The central BCG of A115N hosts the radio source 3C28 which shows a pair of jets, almost perpendicular to the direction of the sucluster's motion. The jets terminate in lobes each of which has a "tail" pointing IN the direction of motion of the subcluster. The Chandra analysis provides details of the merger including the velocities of the subclusters both through analysis of the cold front and a weak shock. The motion of A115N through the cluster generates counter-rotating vortices in the subcluster gas that form the two radio tails. Hydrodynamic modeling yields circulation velocities within the A115N sub cluster. Thus, the radio emitting plasma acts as a dye tracing the motions of the X-ray emitting plasma. A115S shows two "cores", one coincident with the BCG and a second appears as a ram pressure stripped tail.

Author(s): William R. Forman[1]

Institution(s): *1. SAO*

105.18 – Resolving the Extragalactic Gamma-ray Background

Models of the extragalactic gamma-ray background (EGB) show that its intensity can be ascribed to the integrated emission of source populations, like blazars, already detected by the Fermi Large Area Telescope (LAT). Taking advantage of the sensitivity increase delivered by Pass 8, the newest event-level analysis, we tested this hypothesis employing a photon fluctuation analysis above 50 GeV. For the first time we were able to resolve nearly the entire EGB and show that blazars contribute at least 85% of the EGB intensity. We will discuss how this analysis can be extended to lower energies and present our current understanding of the origin of the EGB, its ties to the neutrino flux measured by IceCube and the capability to constrain scenarios of dark matter interaction.

Author(s): Marco Ajello[1], Mattia Di Mauro[2], Silvia Manconi[3], Hannes Zechlin[3]
Institution(s): *1. Clemson, 2. SLAC, 3. Turin University*

105.19 – The Properties of the Diffuse X-ray Background from the DXL sounding rocket mission (plus ROSAT, XMM-Newton and Suzaku data)

Understanding the properties of the different components of the Diffuse X-ray Background (DXB) is made particularly difficult by their similar spectral signature.
The University of Miami has been working on disentangling the different DXB components for many years, using a combination of proprietary and archival data from XMM-Newton, Suzaku, and Chandra, and a sounding rocket mission (DXL) specifically designed to study the properties of Local Hot Bubble (LHB) and Solar Wind Charge eXchange (SWCX) using their spatial signature.
In this talk we will present:
(a) Results from the DXL mission, specifically launch #2, to study the properties of the SWCX and LHB (and GH) and their contribution to the ROSAT All Sky Survey Bands;
(b) Results from a Suzaku key project to characterize the SWCX and build a semi-empirical model to predict the SWCX line emission for any time, any direction. A publicly available web portal for the model will go online by the end of the year;
(c) Results from XMM-Newton deep surveys to study the angular correlation of the Warm-Hot Intergalactic Medium (WHIM) in the direction of the Chandra Deep Field South.
DXL launch #3, schedule for January 2018 and the development of the DXG sounding rocket mission to characterize the GH-CGM emission using newly developed micropore optics will also be discussed.

Author(s): Massimiliano Galeazzi[1]
Institution(s): *1. Univ. of Miami*

105.21 – Unveiling the cosmic history of light

The extragalactic background light (EBL) is the collective emission of all the stars and galaxies over the history of the universe. The most efficient method to study the EBL is through the imprint it leaves via photon-photon annihilation in the spectra of distant gamma-ray sources. Here we present a combined analysis of gamma-ray data from GRBs and blazars detected by Fermi Large Area Telescope. This analysis allows us to probe the EBL up to much higher redshifts ($z>4$) and over a larger wavelength range. The details of this work and its implications will be discussed.

Author(s): Abhishek Desai[1], Marco Ajello[1], Dieter Hartmann[1], Vaidehi Sharan Paliya[1], Justin Finke[4], Nicola Omodei[2], Alberto Dominguez[6], Kári Helgason[3], Manuel Meyer[5]
Institution(s): *1. Clemson University , 2. Kavli Institute for Particle Astrophysics and Cosmol- ogy, 3. Max-Planck-Institut fur Astrophysik, 4. Naval Research Laboratory, 5. Stockholm university, 6. Universidad Complutense de Madrid*

105.22 – The *Swift*/XRT Deep Galactic Plane Survey

The Swift Deep Galactic Plane Survey utilizes XRT (0.3-10 keV) in the first deep, homogeneous and systematic search for magnetars, HMXBs, and transients. Over two years we will survey 40 sq. deg., in the two regions where the Galactic bar meets the Scutum and Perseus Arms (10 deg $< |l| < 30$deg and $|b| < 0.5$ deg) in 366 overlapping 5ks tiles. The survey will be complete to luminosities of $L=1.0 \times 10^{34}$ erg s^{-1} and relies on multi-wavelength archival and follow up data to determine the nature of new sources as well as spectral and temporal variability. The goal of this survey is to better establish the source populations of compact stellar systems by increasing their numbers for statistical studies. We will also constrain the galactic star formation rate and the nature of massive star evolution. Here we present first results from the survey.

Author(s): Nicholas Gorgone[1], Chryssa Kouveliotou[1]
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105.23 – The Hubble Space Telescope Frontier Fields Program

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

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

105.24 – What we have learnt from the Chandra COSMOS Legacy Survey

The Chandra COSMOS Legacy survey covers 2.2 sq deg of the COSMOS field with a uniform depth of 180 ks of exposure and yields a total of 4000 X-ray detected sources. The main goal of the survey was to study the population of high redshift sources, their host properties and their clustering. The data provide very good quality X-ray detections which allowed us to study the obscuration properties as function of redshift and luminosity and to reveal a significant population of Compton Thick AGN. Moreover, beside the X-ray detections, we used the multiwavelength catalogs to study, via stacking analysis, undetected galaxies revealing a population of obscured AGN among elliptical galaxies and intermediate mass black holes in dwarf galaxies. In this talk, I will give an overall summary of the work done and in progress and how these works can inform future mission studies.

Author(s): Francesca M. Civano[1]
Institution(s): *1. SAO*

106 – AGN Poster Session

106.01 – *NuSTAR* constraints on coronal cutoffs in *Swift*-BAT selected Seyfert 1 AGN

The continuum X-ray emission from Active Galactic Nuclei (AGN) is believed to originate in a hot, compact corona above the accretion disk. Compton upscattering of UV photons from the inner accretion disk by coronal electrons produces a power law X-ray continuum with a cutoff at energies determined by the electron temperature.
The *NuSTAR* observatory, with its high sensitivity in hard X-rays, has enabled detailed broadband modeling of the X-ray spectra of AGN, thereby allowing tight constraints to be placed on the high-energy cutoff of the X-ray continuum. Recent detections of low cutoff energies in Seyfert 1 AGN in the *NuSTAR* band have motivated us to pursue a systematic search for low cutoff candidates in *Swift-BAT* detected Seyfert 1 AGN that have been observed with *NuSTAR*. We use our constraints on the cutoff energy to map out the location of these sources on the compactness – temperature diagram for AGN coronae, and discuss the implications of low cutoff energies for the cooling and thermalization mechanisms in the corona.

Author(s): Nikita Kamraj[1], Fiona Harrison[1], Mislav Balokovic[1], Murray Brightman[1], Daniel Stern[2]
Institution(s): *1. California Institute of Technology, 2. Jet Propulsion Laboratory, California Institute of Technology*

106.02 – Multi-Wavelength Analysis of the Quasar CTA102 during a Dramatic Outburst in 2016 December

Abstract: The quasar CTA102 underwent a dramatic outburst from gamma-ray to
radio wavelengths in late 2016. The gamma-ray emission at 0.1-200 GeV rose
up to (12.1+-0.7)x10^{-6} phot/s/cm^2, with a significant flattening of the spectral index. The blazar reached an optical brightness level never observed previously, < 11 mag in R band, and an increase of the radio flux density at millimeter wavelengths with flattening of the radio spectrum was observed as well.
We present analysis of multi-wavelength data during the event obtained at gamma-rays with the Fermi Large Area telescope, at X-rays provided by the NuStar X-ray telescope and Swift XRT and UVOT, in optical bands measured at different telescopes around the world along with polarimetric observations, and at mm-waves obtained at Metsahovi

Radio Observatory and SubMillimeter Array, along with imaging of the
parsec-scale jet of the quasar with the VLBA at 43 GHz.
This research is funded in part by NASA through Fermi Guest Investigator grant NNX14AQ58G and by the National Science Foundation through grant AST-1615796.
Author(s): Svetlana G. Jorstad[2], Alan P. Marscher[2], Karen E. Williamson[2], Valeri M. Larionov [4], Paul S. Smith[5], Mark A. Gurwell[3], Anne Lahteenmaki[1]
Institution(s): *1. Aalto University , 2. Boston Univ., 3. CfA, 4. St.Petersburg State University, 5. Steward Obs.*

106.03 – External Compton Scattering in Blazar Jets

In many low-peaked blazars, especially flat spectrum radio quasars, it is thought that the gamma-rays are produced through the Compton scattering of seed photons external to the jet, most likely from the broad line region and dust torus. I will present detailed, realistic models of broad line regions and dust tori, useful for computation of Compton scattering. I will discuss the location of the gamma-ray emitting region in the context of Compton-scattering of these seed radiation fields.
Author(s): Justin Finke[1]
Institution(s): *1. US Naval Research Laboratory*

106.04 – Self-similar semi-analytical RMHD jet model: first steps towards a more comprehensive jet modelling for data fitting

Jets are ubiquitous and reveal themselves at different scales and redshifts, showing an extreme diversity in energetics, shapes and emission. Indeed jets are found to be characteristic features of black hole systems, such as X-ray binaries (XRBs) and active galactic nuclei (AGN), as well as of young stellar objects (YSOs) and gamma-ray bursts (GRBs). Observations suggest that jets are an energetically important component of the system that hosts them, because the jet power appears to be comparable to the accretion power. Significant evidence has been found of the impact of jets not only in the immediate proximity of the central object, but as well on their surrounding environment, where they deposit the energy extracted from the accretion flow. Moreover, the inflow/outflow system produces radiation over the entire electromagnetic spectrum, from radio to X-rays. Therefore it is a compelling problem to be solved and deeply understood. I present a new integration scheme to solve radial self-similar, stationary, axisymmetric relativistic magneto-hydro-dynamics (MHD) equations describing collimated, relativistic outflows crossing smoothly all the singular points (the Alfvén point and the modified slow/fast points). For the first time, the integration can be performed all the way from the disk mid-plane to downstream of the modified fast point. I will discuss an ensemble of jet solutions showing diverse jet dynamics (jet Lorentz factor ~ 1-10) and geometric properties (i.e. shock height ~ 10^3 - 10^7 gravitational radii), which makes our model suitable for application to many different systems where a relativistic jet is launched.
Author(s): Sera Markoff[3], Chiara Ceccobello[3], Martin Heemskerk[3], Yuri Cavecchi[2], Peter Polko[3], David Meier[1]
Institution(s): *1. California Institute of Technology, 2. Princeton University, 3. University of Amsterdam*

106.05 – Illuminating Radio Dim/Gamma-ray Bright Active Galactic Nuclei

A recent survey of high-latitude gamma-ray sources by Schinzel et al. (arXiv:1702.070336), reveals a sample of about 100 objects which are not detected in the 4-10 GHz radio band to a limiting flux of about 2mJy. This apparent lack of radio flux is puzzling, and may indicate either an extreme Compton-dominated sample, or copious gamma-ray emission from a heretofore unknown population such as a subclass of radio-quiet AGN. To further investigate the nature sources, we have undertaken the task of searching for transient or faint steady emission in the ~15-100-keV X-ray band using the Swift/BAT archive. Here we discuss the analysis, detection's (or not) , and any spectral or temporal information that may enable us to assess the nature of these sources.
Author(s): Daryl J. Macomb[1], Amanda Bohney[1], Chris R. Shrader[2]
Institution(s): *1. Boise State Univ., 2. NASA/Goddard Space Flight Center*

106.06 – X-ray Observations of the Radio-loud Narrow-Line Seyfert 1 Galaxy PMN J0948+0022

We report on the 200-ks NuSTAR observation of the narrow-line Seyfert 1 (NLS1) AGN, PMN J0948+0022, executed simultaneously with an 80-ks XMM-Newton observation in 2016. PMN J0948+0022 was chosen because it is one of seven known, powerfully-jetted radio-loud (RL) NLS1s that have been observed with Fermi. We will detail our progress toward meeting the following campaign objectives with the analysis of these datasets: (1) Confirming the presence of the soft excess and look for any evidence of reflection, either in Fe K emission or the Compton hump above 10 keV; (2) Determining the correct spectral model across the entire X-ray bandpass (e.g., Comptonization vs. blurred reflection for the soft excess); (3) Measuring the coronal parameters (temperature, optical depth, compactness) by constraining the high-energy cutoff of the power-law and the low-energy UV/optical data simultaneously; (4) Looking for any correlations between the corona, jet and accretion properties by examining radio and Fermi monitoring of the source contemporaneous with the X-ray and UV/optical data and comparing fits to pure

disk/corona models vs. jet models; (5) Furthering our understanding of the jet emission mechanism(s) in RLNLS1s by adding new information to the SED modeling of this source.

Author(s): Laura Brenneman[3], Christopher S. Reynolds[4], Sera Markoff[1], Michael Parker[2], Jon M. Miller[5]
Institution(s): *1. Anton Pannekoek Institute for Astronomy, 2. Cambridge University, 3. Smithsonian Astrophysical Observatory, 4. University of Maryland, 5. University of Michigan*

106.07 – Discovering structure and evolution within the coronae of Seyfert galaxies

Detailed analysis of the reflection and reverberation of X-rays from the innermost regions of AGN accretion discs reveals the structure and processes that produce the intense continuum emission and the extreme variability we see, right down to the innermost stable orbit and event horizon of the black hole. Observations of Seyfert galaxies spanning more than a decade have enabled measurement of the geometry of the corona and how it evolves, leading to orders of magnitude in variability. They reveal processes the corona undergoes during transient events, notably the collimation and ejection of the corona during X-ray flares, reminiscent of the aborted launching of a jet.

Recent reverberation studies, of the Seyfert galaxy I Zwicky 1 with XMM-Newton, are revealing structures within the corona for the very first time. A persistent collimated core is discovered, akin to the base of a jet embedded in the innermost regions alongside an extended corona related to the accretion disc. The detection of the flare in the X-ray emission enables the evolution of both the collimated and extended portions of the corona to be tracked. The flare is seen originating as an increase in activity above the accretion disc before propagating inwards, energising the collimated core at a later time, leading to a second sharp increase in the X-ray luminosity.

This gives us important constraints on the processes by which energy is liberated from black hole accretion flows, how they are governed over time and how jets are launched, giving us the deepest insight to date of how these extreme objects are powered.

Author(s): Daniel Wilkins[3], Luigi C. Gallo[1], Catia Silva[2], Elisa Costantini[2]
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106.08 – Accretion disk reverberation with Hubble Space Telescope observations of NGC 4593

Irradiation of the accretion disk by X-ray/EUV photons should lead to wavelength-dependent UV/optical continuum time lags as the hotter, inner parts of the disk will see the variable irradiating flux before the cooler, outer parts of the disk. Recently, there has been a significant improvement in wavelength-dependent lag measurements from high-cadence monitoring and a picture is emerging that the accretion disk sizes are a factor of 2 - 3 larger than predicted by the standard disk model. We obtained Hubble Space Telescope spectroscopy of NGC 4593 as part of a larger multi-wavelength reverberation mapping campaign including monitoring by Swift and Kepler. From 2016 July 12 to 2016 August 6 we performed 26 observations with an approximately daily cadence using the Space Telescope Imaging Spectrograph. The spectra cover a nearly continuous wavelength range from approximately 1150 - 10000Å. The continuum is significantly variable at all wavelengths, with variations at 1150Å leading variations at 8950Å by approximately 1.2 days. In the scenario where X-rays or EUV photons drive variability in the accretion disk the time lags should follow $\lambda^{4/3}$. Here, we see a significant deviation from this around the Balmer jump, indicating a large contribution to the lags from diffuse continuum emission in the broad line region. However, even when taking this diffuse continuum lag into account, we still find that the accretion disk lags are a factor of about 3 larger than expected from the standard disk model.

Author(s): Edward Cackett[5], Ian McHardy[3], Keith D. Horne[4], Michael Goad[1], Rick Edelson[2], Kirk T. Korista[6], Chia-Ying Chiang[5]
Institution(s): *1. University of Leicester, 2. University of Maryland, 3. University of Southampton, 4. University of St Andrews, 5. Wayne State University, 6. Western Michigan University*

106.09 – Obscured Supermassive Black Hole Growth - Connections to Host Galaxies and Evolutionary Models

A large fraction of the supermassive black hole growth in the Universe is hidden from view behind thick columns of dust. The most heavily obscured quasars can be challenging to detect even with current high energy X-ray observatories such as *NuSTAR* – however with infrared observations that can detect the hot nuclear dust in even the most enshrouded systems, we are now beginning to characterize large populations of these hidden monsters.

With roughly half-a-million quasars selected with *WISE*, we have found via clustering and CMB lensing cross-correlation measurements that obscured quasars reside in dark matter halos 0.5 dex more massive than unobscured quasars. This implies that obscuration is directly linked to host galaxy properties, and not simply the dust geometry around the quasar. Using cross-correlations we accurately characterize the redshift distribution of the obscured quasar population, confirming that it peaks at z = 1, and using long-wavelength bands find that it has a similar bolometric luminosity distribution as unobscured quasars as well. Finally, using a simple model based on empirical relationships between halo, stellar, and black hole masses, we show that an evolutionary sequence from obscured to unobscured quasar, combined with a flux limit, can predict the observed halo mass differences.

Studies of the most obscured quasars provide valuable insights on the rapid growth of the most massive black holes in the Universe, and motivates future work with the next generation high energy observatories such as *eROSITA*, *Athena*, and *Lynx*.

Author(s): Michael A. DiPompeo[1], Ryan C. Hickox[1], Adam D. Myers[2]
Institution(s): *1. Dartmouth College, 2. University of Wyoming*

106.10 – Circumnuclear Star Formation and Heavy Obscuration Revealed by *Chandra* in NGC 4968

NGC 4968 is a nearby Seyfert 2 galaxy with evidence of extreme obscuration and circumnuclear star formation in its *Chandra* spectrum. Imaging analysis in the soft band (0.5 - 2 keV) reveals extended (~1 kpc) emission that is thermal in nature and ascribed to on-going star formation. We measure an Fe Kα equivalent width (EW) value of ~2.5 keV which is a clear indicator of Compton-thick levels of obscuration. Using physically motivated X-ray spectral models that self consistently treat the transmitted continuum, Compton scattered emission, and fluorescent line emission, we measure a column density above 1.25 x 10^{24} cm^{-2}, though are unable to determine, with present data, whether the X-ray reprocessor takes the form of a toroidal or spherical geometry (in which case the column density may exceed 10^{25} cm^{-2}). A spherical distribution of matter facilitiates the production of extreme Fe Kα EWs, suggesting that this geometry may be preferred. We speculate that on-going star formation increases the covering factor of the circumnuclear obscuration enshrouding the AGN. With upcoming *NuSTAR* observations, we will test whether the X-ray reprocessor geometry is indeed spherical and derive better constraints on the obscuring column density.

Author(s): Stephanie M. LaMassa[2], Tahir Yaqoob[4], Nancy Levenson[2], Peter Boorman[5], Timothy M. Heckman[3], Poshak Gandhi[5], Jane R. Rigby[1], C. Megan Urry[6], Andrew Ptak[1]
Institution(s): *1. NASA Goddard Space Flight Center, 2. Space Telescope Science Institute, 3. The Johns Hopkins University, 4. UMBC, 5. University of Southhampton, 6. Yale University*

106.11 – Relative Timing of X-ray, UV, and Optical Dips in the Radio Galaxy 3C 120

We have recently completed a year-long program to monitoring the FR 1 radio galaxy 3C 120 at optical, UV, and X-ray bands with the Swift satellite. The light curves reveal several sharp dips in the X-ray, UV, and optical flux. During this period, a number of superluminal knots appeared in the jet, as seen in our approximately monthly 43 GHz VLBA images. The relative timing of the flux minima at the different bands provides information on the locations of the emission sites in the accretion disk-corona system. The relationship between the dips and delayed passage of new knots through the stationary core, situated about 0.5 pc downstream of the black hole, sheds light on the disk-jet connection. The presentation will compare the results of the authors' analysis of the data with the expectations of various theoretical models for the inner disk-corona.

This research was supported in part by NASA through the Swift and Fermi guest investigator programs, grants NNX16AN69G and NNX14AQ58G.

Author(s): Alan P. Marscher[1], Svetlana G. Jorstad[1], Karen E. Williamson[1]
Institution(s): *1. Boston Univ.*

106.12 – Tip of the iceberg? Selection effects in X-ray AGN and their impact on black hole-galaxy evolution studies

Our understanding of the connection between AGN and their host galaxies and the underlying properties of the full AGN population is presently limited by complex observational biases that are difficult to untangle using conventional methods and theoretical models. To more completely explore these selection effects, we use a semi-numerical galaxy formation simulation along with a universal Eddington ratio distribution, as determined by Jones et al. (2016) from SDSS data, to describe the multi-wavelength AGN population. In particular, we explicitly model selection effects to produce the “observed” AGN population for comparison with both theoretical and observational X-ray data. We investigate the impact on the “observed” population of selecting AGN in the X-rays based on thresholds in luminosity (as they are selected in most surveys). We find that we can broadly reproduce the host galaxies and halos of the X-ray AGN population, and that different AGN selection techniques yield samples with very different host galaxy properties. Furthermore, we discuss the capabilities of using this technique to build synthetic SEDs in order to explore the synthesis of the X-ray background.

Author(s): Mackenzie L. Jones[1], Ryan C. Hickox[1], Simon Mutch[4], Darren Croton[3], Andrew Ptak[2], Michael A. DiPompeo[1]

Institution(s): *1. Dartmouth College, 2. GSFC, 3. Swinburne University, 4. University of Melbourne*

106.13 – A First-Principles Spectral Model for Blazar Jet Acceleration and Emission with Klein-Nishina Scattering of Multiple Broad Line Region Emission Lines

Blazars are a sub-class of active galactic nuclei, with a polar jet aligned along our line of sight. Emission from blazar jets is observed across the electromagnetic spectrum. In our model we assume that the emission emanates from one homogeneous zone in the jet, which is in the process of passing through the Broad Line Region (BLR). We start from first-principles to build up a particle transport model, whose solution is the electron distribution, rather than assuming a convenient functional form. Our transport model considers shock acceleration, adiabatic expansion, stochastic acceleration, Bohm diffusion, synchrotron radiation, and Klein-Nishina radiation pulling seed photons from the BLR and dusty torus. We obtain the steady-state electron distribution computationally, and calculate individual spectral contributions due to synchrotron with self-absorption, disk, synchrotron self-Compton, and external-Compton emission, using numerical integration. We compare the resulting radiation spectrum with multi-wavelength data for 3C 279, during quiescence and two flares. Our preliminary results suggest that the jet emission is produced in a region with a sub-equipartition magnetic field, and that the magnetic field in the jet decreases during flaring events, implying that reconnection may play a role in blazar flares.

Author(s): Tiffany R Lewis[1], Justin Finke[2], Peter A. Becker[1]
Institution(s): *1. George Mason University, 2. Naval Research Laboratory*

106.14 – Are there multiple gamma-ray emission sites in blazars?

We present an investigation of parsec-scale jet morphology evolution in the blazar 3C 279 during an episode of extreme flaring activity at GeV energies in 2014 using 43 GHz VLBI jet images. The study made use of Pass 8 Fermi/LAT and 43 GHz VLBI data. The primary goal is to explore the total intensity and polarization properties and their connection with the broadband flux variations observed during a bright gamma-ray activity phase of the source. We noticed two different modes of high-energy emission; one acoompained by simultaneous ejection of a component (plasma blob) and another followed by the ejection of a component from the core. Our study supports multiple sites of gamma-ray emission in 3C 279.

Author(s): Bindu Rani[1]
Institution(s): *1. NASA GSFC*

106.15 – Compton thick AGN in the NuSTAR era

The recent launch of the Nuclear Spectroscopic Telescope Array (NuSTAR), the first telescope with focusing optics at >10 keV, represented a major breakthrough in the study of obscured active galactic nuclei (AGN). In this talk, I present the results of the 0.3-100 keV spectral analysis of the 30 Compton thick (CT-; i.e., those sources having column density N_H>1E24 cm^{-2}) AGN detected within z~0.1 in the BAT 100-month survey with available NuSTAR data. Particularly, I will focus on how adding NuSTAR data to the 0.3-10 keV information helps to characterize the CT-AGN population, significantly improving the measurements of important X-ray spectral parameters such as the photon index, the intrinsic absorption, the intensity of the Iron K alpha line at 6.4 keV and the obscuring torus opening angle. Finally, I will discuss the role of these objects in the context of obscured AGN accretion physics, and their contribution to the cosmic X-ray background.

Author(s): Stefano Marchesi[1], Marco Ajello[1], Lea Marcotulli[1], Andrea Comastri[2]
Institution(s): *1. Clemson University, 2. INAF-OABO*

106.16 – Modeling of the Microlensed Fe Kα Emission from the Quasar RX J1131-1231

We present the results of detailed general relativistic ray tracing simulations of the microlensed Fe Kα emission from the gravitationally lensed quasar RX J1131-1231. The microlensing can amplify the extremely red and blueshifted emission from the innermost parts of the accretion flow. We present a systematic exploration of the quasar and microlensing parameter spaces. The comparison of the simulated energy spectra with RX J1131-1231 energy spectra obtained with the Chandra X-ray telescope allows us to constrain the spin and inclination of the black hole and the properties of the lensing galaxy including its stellar to dark matter mass ratio.

Author(s): Henric Krawczynski[2], George Chartas[1]
Institution(s): *1. College of Charleston, 2. Washington Univ, St. Louis*

106.17 – Anisotropic Particle Acceleration in Relativistic Shear Layers

We present results of Particle in Cell (PIC) simulations of relativistic shear layers as relevant to the relativistic jets of acive galactic nuclei and gamma-ray bursts. We study the self-generation of electro-magnetic fields and particle acceleration for various different plasma compositions (electron-ion vs. electron-positron pair vs. hybrid). Special emphasis is placed on the angular distribution of accelerated particles. We find that electron-ion shear layers lead to highly anisotropic particle distributions in the frame of the fast-moving inner spine. The beaming pattern of the highest-energy particles is much narrower than the characteristic beaming angle of 1/Gamma resulting from relativistic aberration of a co-moving isotropic distribution. This may pose a possible solution to the Lorentz-Factor crisis in blazars and explain very hard X-ray / soft gamma-ray spectra of some gamma-ray bursts.

Author(s): Markus Boettcher[1], Edison P. Liang[2], Wen Fu[2]
Institution(s): *1. North-West University, 2. Rice University*

106.18 – Effects of AGN Feedback on the evolution of Early Type Galaxies: hot accretion flows and galactic rotation

The vast studies of AGN feedback in both observation and theory for the past decade reveal that the feedback plays a critical role in terminating star formation in the galactic bulge and regulating the AGN activities and the growth of the central black hole through the lack of fuel for accretion. However, the exact mechanism of the co-evolution between the black holes and the host galaxies remains uncertain, and the theoretical study of this topic is still challenging because of a wide range of dynamic scale from sub pc scale of nuclei to several hundreds kpc scale of galaxies. I will present two projects to help better understanding the effects of the feedback on the evolution of Early Type Galaxies (ETGs). First, I will discuss on the role of hot accretion flow in the feedback. It is widely believed that AGNs spend their most of time in radio-mode, but in many studies, the hot accretion flow is treated with over-simplified model, which is not consistent with reality. We adopt new radiative efficiency profile and develop updated model of hot accretion flow into our numerical study of AGN feedback (both radiative and mechanical feedback). Second, I will discuss how AGN feedback affects the galactic evolution when the host galaxy has an intrinsic high angular momentum. Many recent observations (e.g. ATLAS3D) reveal that large portion of ETGs has a systematic rotation and disk structure in the mid-plane. However, considering galactic rotation in the study of AGN feedback has been technically challenging because of difficulties in the implementation of black hole feeding. To resolve the difficulties, we improve the numerical models, applying 'gravitational torque' mechanism to transport angular momentum outward so that accretion can occur and the AGN can be activated. With such non-negligeable angular momentum, I will discuss the role of both radiative feedback and mechanical feedback, how they affect the physical properties of black hole and host galaxy: black hole mass growth, star formation, duty cycle and X-ray emission.

Author(s): Doosoo Yoon[1], Feng Yuan[1], Zhaoming Gan[1]
Institution(s): *1. Shanghai Astronomical Observatory, CAS*

106.19 – Filling a SMBH accretion disk atmosphere at small and intermediate radii

The medium above an accretion disk is highly diluted and hot. An efficient mechanism to deliver particles and dust grains is an open question; apparently, different processes must be in operation. We discuss an interplay of two different scenarios, where the material is elevated from the plane of an equatorial accretion disk into a corona near a supermassive black hole: (i) an electromagnetically induced transport, which can be driven by magnetic field of stars passing across an accretion disk (Karas et al., 2017); and (ii) radiatively driven acceleration by radiation emerging from the disk (Czerny et al 2015), which can launch a dusty wind near above the dust sublimation radius. The former process can operate in the vicinity of a supermassive black hole (SMBH) surrounded by a dense nuclear star-cluster. The latter process involves the effect of radiation pressure from various sources - stars, accretion disc, and the central accreting SMBH; it can help filling the Broad-Line Region against the vertical component of the black hole gravitational attraction and the accretion disk self-gravity at radius about a few $\times 10^3 R_g$.

Author(s): Vladimir Karas[1], Bozena Czerny[2], Devaky Kunneriath[3]
Institution(s): *1. Astronomical Institute, 2. Center for Theoretical Physics, 3. National Radio Astronomy Observatory*

106.20 – New models for the CLUMPY AGN obscurer

It is clear today that the obscurer of active galactic nuclei (AGN), the 'torus', is more complex than a donut -- a model still often used in X-ray analyses. A realistic model needs to explain X-ray eclipse events and the column density distribution of the AGN population. We construct a new clumpy torus model with these constraints, and Monte Carlo simulate X-ray spectra. Further we consider recent hydrodynamic simulations. Testing against NuSTAR spectra of several Compton-thick AGN, we discover the ubiquitous need for another component: a highly covering, inner Compton-thick reflector. Physical interpretations of this component include a warped (maser) disk or the inner torus wall where clouds launch. We release new xspec tables for our model, with both the inner reflector and the cloud population free to vary in covering factor. Our model can be used self-consistently with CLUMPY infrared emission models for multi-wavelength analyses.

Author(s): Johannes Buchner[3], Murray Brightman[1], Kirpal Nandra[2], Franz E. Bauer[3], Robert Nikutta[3]
Institution(s): *1. Caltech, 2. MPE, 3. PUC*

106.21 – Photometric Redshifts of High-z BL Lacs from 3FGL Catalog

Determining redshifts for BL Lacertae (BL Lac) objects using the traditional spectroscopic method is challenging due to the absence of strong emission lines in their optical spectra. We employ the photometric dropout technique to determine redshifts for this class of blazars using the combined 13 broad-band filters from *Swift*-UVOT and the multi-channel imager GROND at the MPG 2.2 m telescope at ESO's La Silla Observatory. The wavelength range covered by these 13 filters extends from far ultraviolet to the near-Infrared. We report results on 40 new Fermi detected BL Lacs with the photometric redshifts determinations for 5 sources, with 3FGL J1918.2-4110 being the most distance in our sample at z=2.16. Reliable upper limits are provided for 20 sources in this sample. Using the highest energy photons for these Fermi-LAT sources, we evaluate the consistency with the Gamma-ray horizon due to the extragalactic background light.

Author(s): A. Kaur[1], Arne Rau[2], Marco Ajello[1], Vaidehi Paliya[1], Dieter Hartmann[1], Jochen Greiner[2], Jan Bolmer[2], Patricia Schady[2]
Institution(s): *1. Clemson University, 2. MPE*

106.22 – Multiwavelength polarimetry and integrated MHD+Polarized Radiation simulation reveal the blazar flaring mechanism

In addition to multiwavelength variability, blazar polarization signatures are highly variable. Optical polarimetry has shown two distinct features: first, in both quiescent and flaring states, blazar polarization degree generally stays around 10% to 30%; second, after major polarization variations, such as polarization angle swings, the polarization degree quickly restores to its initial state. We have performed integrated relativistic magnetohydrodynamic (MHD) + radiation and polarization simulations of the blazar emission region. Our approach evolves the magnetic fields and flows using the first principles, so we can calculate the spatial and temporal dependent polarization signatures and compare them with observations.Our results show that the above two observational trends indicate the blazar flaring region should be strongly magnetized with the magnetic energy density higher than the plasma rest mass energy density. In such an environment, the 3D kink instability may trigger magnetic reconnection to accelerate particles and give rise to flares. In view of future high-energy polarimetry, this integrated MHD+polarization simulation technique will deliver new constraints on jet's physical conditions and particle acceleration mechanisms.

Author(s): Haocheng Zhang[2], Hui Li[1], Gregory B. Taylor[2]
Institution(s): *1. Los Alamos National Laboratory, 2. University of New Mexico*

106.23 – The challenge of rapid gamma-ray variability of blazar 3C 279

Detections of gamma-ray variability of active galaxies on time scales of a few minutes revealed the most extreme regimes of dissipation and particle acceleration in relativistic plasmas. Observations of blazar 3C 279 by the Fermi Large Area Telescope during a successful Target-of-Opportunity pointing campaign in June 2015 detected very clearly and for the first time variability in the GeV band on time scales 5 minutes and possibly shorter. This result presents a unique challenge for the theory of relativistic jets, since 3C 279 is also a quasar with dense radiative environment that can readily absorb gamma rays produced at sub-pc distance scales. The parameters required to explain such variability are extreme, regardless of the assumption of the radiation mechanism (inverse Compton, synchrotron, lepto-hadronic). Very high bulk Lorentz factors, Gamma ~ 100, and kinetic beaming effect of relativistic magnetic reconnection are proposed as ingredients of a complete solution to this problem that remains elusive.

Author(s): Krzysztof Nalewajko[4], Masaaki Hayashida[2], Greg Madejski[3], Maria Petropoulou[1]
Institution(s): *1. Department of Physics and Astronomy, Purdue University, 2. Institute for Cosmic-Ray Research, University of Tokyo, 3. Kavli Institute for Particle Astrophysics and Cosmology, SLAC National Accelerator Laboratory and Stanford University, 4. Nicolaus Copernicus Astronomical Center*

106.24 – Chasing the most powerful blazars

High-redshift blazars are some of the most extreme sources in the Universe. With jet power exceeding 10^47 erg s-1, they host billion solar masses black holes and are found up to when the Universe was only two billions years old. These sources are of great astrophysical interest as they provide us crucial information about the origin and growth of supermassive black-holes in the early Universe. Detections in the hard X-rays and gamma-rays are desired to find the most powerful objects of this class. With the advent of the Nuclear Spectroscopic Telescope Array (NuSTAR) and the Fermi Large Area Telescope (LAT), it has been possible to increase the sample of high-redshift blazars and to constrain more accurately their physical properties. The improved sensitivity of the LAT has also allowed gamma-ray detection of such sources up to redshift 4.3. Here we present the latest high-redshift blazar detection with NuSTAR and the LAT, and discuss some of their implications.

Author(s): Lea Marcotulli[2], Vaidehi Paliya[2], Marco Ajello[2], Dario Gasparrini[1], Roopesh Ojha[3]
Institution(s): *1. ASI, 2. Clemson University, 3. NASA*

106.26 – Constraints on the Geometry of the Obscuring Torus from the NuSTAR Survey of the Local Seyfert II Population

The obscuring torus is one of the main components of the basic unified model of active galactic nuclei (AGN), needed to create anisotropy in obscuration as a function of the viewing angle. We present the first study of the geometrical properties of the AGN torus in a large and representative sample of type II Seyfert nuclei. The sample consists of 124 AGN selected in the hard X-ray band from the Swift/BAT 70-month catalog and observed simultaneously with NuSTAR and Swift/XRT. These data enable us to explore the constraints that observed spectra place on the properties of the obscuring torus in individual AGN and in the local population of Seyfert II nuclei. We make use of empirically motivated spectral models for X-ray reprocessing in approximately toroidal geometry for constraining the distribution of the average column density of the torus, and the distribution of the torus covering factor within this sample. We find that the torus-averaged column density is independent of the line-of-sight column density, with typical column density that is borderline Compton-thick, i.e., around the unity optical depth for Compton scattering. The distribution of torus covering factors is broad but shows a preference for high covering, peaking around the covering factor of 90%, with the median at 70%, in agreement with recent sample studies in the infrared band. We also examine the dependence of the covering factor on intrinsic luminosity, finding that the median covering factor peaks around the intrinsic X-ray luminosity of 10^42.5 erg/s and decreases toward both lower and higher luminosities.

Author(s): Mislav Balokovic[1], Fiona Harrison[1], Murray Brightman[1]
Institution(s): *1. California Institute of Technology*

106.27 – The kinetic flux of X-ray jets, and a connection to spinning super-massive black holes

We use the kinetic fluxes measured for 100 kpc X-ray jets to calculate the required mass loss for rapidly spinning supermassive black holes to supply the power. For the quasars in the survey by Marshall et al. (2005, 2011, 2017, submitted) this power can be accommodated, even with parameterized spins as low as a=0.2. If we assume the initial power is purely Poynting flux, then since the magnetic field carries both the energy and the angular momentum lost by the black hole, we can derive constraints on the magnetic field as a function of jet radius, r. This must break down at some distance prior to the initiation of radiation from the jet; e.g., where particles are accelerated.

Author(s): Daniel A. Schwartz[1]
Institution(s): *1. Harvard-Smithsonian, CfA*

106.28 – Fermi non-detections of four Anomalous X-ray Jet Sources and Implications for the IC/CMB Mechanism

The Chandra X-ray observatory has discovered kpc-scale X-ray jets in many powerful quasars over the past 2 decades (Harris & Krawczynski, 2006). In many cases these X-rays cannot be explained by the extension of the radio-optical spectrum produced by synchrotron-emitting electrons in the jet, since the observed X-ray flux is too high and/or the X-ray spectral index is too hard. A widely accepted model for the X-ray emission, first proposed by Celotti et al. (2001) and Tavecchio et al. (2000), posits that the X-rays are produced when relativistic electrons in the jet up-scatter ambient cosmic microwave background (CMB) photons via inverse Compton scattering from microwave to X-ray energies (the IC/CMB model). However, explaining the X-ray emission for these jets with the IC/CMB model requires high levels of IC/CMB γ-ray emission (Georganopoulos et al., 2006), which we are looking for using the Fermi/LAT γ-ray space telescope. Another viable model for the large scale jet X-ray emission, favored by the results of Meyer et al. (2015) and Meyer & Georganopoulos (2014), is a second population of synchrotron-emitting electrons with up to multi-TeV energies. In contrast with the second synchrotron interpretation; the IC/CMB model requires jets with high kinetic powers which can exceed the Eddington luminosity which remain highly relativistic ($\Gamma \approx 10$) up to kpc scales. I will present recently obtained deep γ-ray upper-limits from the Fermi/LAT which rule out the IC/CMB model in four sources previously modeled with IC/CMB, and discuss the properties of the growing sample of non-IC/CMB anomalous jets and the implications for jet energetics and environmental impact.

Author(s): Peter Breiding[1], Eileen T. Meyer[1], Mary Keenan[1], Natalie Denigris[1], Markos Georganopoulos[1], Jennifer Hewitt[1]
Institution(s): *1. University of Maryland, Baltimore County*

106.29 – A deep NuSTAR observation of M51: Investigating its Compton-thick nucleus, LINER companion and ULXs above 10 keV

We present the results from a deep 200ks observation of M51 with NuSTAR. This observation was taken simultaneously with Chandra to provide soft-X-ray-coverage as well as to resolve the different point sources. We detect the Compton-thick nucleus of M51a, the LINER nucleus of M51b and several ultraluminous X-ray sources located in the galaxies above 10 keV. From X-ray torus modeling, we find that the covering factor of the torus in the nucleus of M51a is ~40% and supports a decline in the obscured fration at low X-ray luminosities. We find that the X-ray spectrum of the intermediate mass black hole candidate, ULX-7, is consistent with a power-law up to high energies, supporting its IMBH status. We further resolve the nucleus of M51b into two X-ray sources with Chandra, and measure its X-ray luminosity.

Author(s): Murray Brightman[1], Ady Annuar[3], David M Alexander[3], Hannah Earnshaw[3], Poshak Gandhi[7], Ann E. Hornschemeier[5], Bret Lehmer[8], Andrew Ptak[5], Blagoy Rangelov[4], Tim P Roberts[3], Daniel Stern[6], Andreas Zezas[2]
Institution(s): *1. California Institute of Technology, 2. Center for Astrophysics, 3. Durham University, 4. George Washington University, 5. Goddard Space Flight Center, 6. JPL, 7. Southampton University, 8. University of Arkansas*

106.30 – The broad-band X-ray spectra of Mrk 926, 4U 1344-60 and ESO 141-G055

Mrk 926, 4U 1344-60 and ESO 141-G055 are bright Seyfert 1 galaxies that contrary to many of the Seyfert 1s studied in-depth with NuSTAR do not show signs of relativistic reflection. We present results from the spectroscopic analyses of simultaneous Swift-NuSTAR or in case of Mrk 926 XMM-NuSTAR observations of these three AGN. The broad-band spectral coverage and the simplicity of the spectra allows us to measure the primary emission with great accuracy. We use the results from our spectral studies and others in the literature to explore whether the differences in reflection-strength in bright Seyfert 1s coincide with any differences in the Comptonization parameters. This allows us to test the hypothesis that the detection of a relativistic reflection component is geometry-driven.

Author(s): Anne Lohfink[1], Andrew C Fabian[2], Douglas Buisson[2], Erin Kara[3], Christopher S. Reynolds[3]
Institution(s): *1. Montana State University, 2. University of Cambridge, 3. University of Maryland*

106.31 – Evidence for a TDE Origin for the Radio Transient in Cygnus A

Recently new JVLA observations by Perley et al. (2017) have revealed evidence for a luminous radio transient at a projected distance of 0.46 kpc from the nucleus of Cygnus A. Based on data taken between 1989 and 2016, the flux density of this radio transient has risen from an upper limit of <0.5 mJy to 4 mJy at a frequency of 8.5 GHz. Additional VLBA observations at 8 GHz by the same authors confirm this transient source to be compact (<4 pc) and coinciding with a source seen previously in optical and NIR images. Perley et al. (2017) have interpreted this source to be a secondary supermassive black hole in a close orbit around the Cygnus A nucleus. Several explanations have been proposed for the turn-on of the Cygnus A-2 transient over the 9 year timeframe including variability in the accretion onto this secondary BH and alternatively a possible tidal disruption event (TDE).

We present the results of a new X-ray analysis utilizing new and archival data from the Chandra and Swift satellites. Cygnus A has been observed multiple times by Chandra between 2000, 2005, and 2015-2017. The Swift satellite performed 9 observations of Cygnus A between 2006 and 2017. Based on these observations, we present evidence for a decline in the flux of the Cygnus A nucleus, with the soft X-ray flux (0.3-1.2 keV) showing a drop by a factor of 2 between 2000 and 2005. The Swift observations confirm the X-ray emission from the Cygnus A continued to fade after 2006. As the radio source was last undetected in 1997, these data constrain the peak of the X-ray emission and the likely onset of brightening in the radio to a window of 3 years or less. This timescale implies a very rapid onset of accretion onto the secondary black hole and strongly favors the TDE interpretation for the origin of the Cygnus A-2 radio transient. Chandra images of the 3 kpc x 3 kpc region around the Cygnus A nucleus show clear evidence for an extended region of soft X-ray emission dimming on this timescale, which we interpret as fading reflected nuclear emission from surrounding dust. In this presentation, we summarize these results and their implications in light of a TDE origin for the observed X-ray and radio variability.

Author(s): Michael W Wise[1], Martijn de Vries[3], Antonia Rowlinson[1], Paul Nulsen[2], Bradford Snios[2], Mark Birkinshaw[4], Diana Worrall[4]
Institution(s): *1. ASTRON (Netherlands Institute for Radio Astronomy), 2. SAO, 3. University of Amsterdam, 4. University of Bristol*

106.32 – Gamma-ray Emitting Narrow Line Seyfert 1 Galaxies in SDSS-DR12

The detection of significant γ-ray emission from radio-loud narrow line Seyfert 1 galaxies (NLSy1s) enables to study the properties of relativistic jets at different jet launching environment than that generally claimed for blazars. Here, we report the first detection of the significant γ-ray emission from AGNs which are recently classified as NLSy1 from their SDSS optical spectrum. Comparing the γ-ray properties of these objects with 3LAC blazars reveals their spectral shapes to be similar to FSRQs, however, with low γ-ray luminosity (≤1046–47 erg s−1). Moreover, in the WISE color-color diagram, these objects occupy a region mainly populated by FSRQs, thus indicating γ-NLSy1s to be the low black hole mass counterpart of powerful FSRQs.

Author(s): Vaidehi Sharan Paliya[1]
Institution(s): *1. Clemson University*

106.33 – Harnessing the full power of the widest Chandra field: average accretion rates of black holes in SDSS galaxies through X-ray stacking

Galaxy-scale bars are expected to provide an effective means for driving material towards the central region in spiral galaxies, and possibly feeding supermassive black holes (BHs). I will present our latest results on a statistically-complete study of the effect of bars on average BH accretion. From a well-selected sample of over 50,000 spiral galaxies extracted from the Sloan Digital Sky Survey, we separate those sources considered to contain galaxy-scale bars from those that do not. Using the first 16 years worth of data taken by the Chandra X-ray Observatory, we identify X-ray luminous AGN and perform the widest-area X-ray stacking analysis to date on the remaining X-ray undetected sources. Through our X-ray stacking, we derive a time-averaged look at accretion for galaxies at fixed stellar mass and star formation rate, finding that the average nuclear accretion rates of galaxies with bar structures are fully consistent with those lacking bars, and robustly concluding that large-scale bars have little or no effect on the average growth of BHs in nearby (z < 0.15) galaxies over gigayear timescales.

Author(s): Andy D. Goulding[4], Jenny E. Greene[4], Ryan C. Hickox[1], David M Alexander[2], William R. Forman[3], Christine Jones[3], Bret Lehmer[5]
Institution(s): *1. Dartmouth College, 2. Durham University, 3. Harvard Smithsonian, CfA, 4. Princeton University, 5. University of Arkansas*

106.34 – The Intrinsic Demographics of Blazars

Blazar surveys over the past three decades have revealed a range of spectral energy distributions (SEDs), with large systematic differences depending on survey wavelength. This means blazar samples suffer from strong selection effects. To date there has been no agreement on how to infer intrinsic population demographics from these samples, with a key issue being whether blazar jet power is related to the shape of the spectral energy distribution. We investigate this issue using Monte Carlo simulations of BL Lac and flat-spectrum radio quasar populations. We rule out the hypothesis that the SED shape is *not* linked to luminosity, as the simulated samples in that case disagree strongly with observed surveys. This means that the low-power blazars found primarily in X-ray surveys must be more common than the high-power blazars found primarily in radio surveys. Given an intrinsic correlation between luminosity and SED shape, our simulations predict distributions of flux, redshift, luminosity, and spectral index consistent with existing surveys. We also show that the observed evolution of X-ray-selected blazars, as measured through the average V/V_{max} ratio, appears to be negative even when the underlying evolution is actually mildly positive. The apparent negative evolution of X-ray bright BL Lacs is a selection effect caused by redshifting a steeply falling UV-to-X-ray spectrum out of the X-ray band. As this conclusion would suggest, our simulations also show that the deeper the X-ray flux limit and/or the lower the frequency of the synchrotron peak in the SED, the less negative the apparent evolution.

Author(s): C. Megan Urry[2], Peiyuan Mao[2], Timothy D Brandt[1]
Institution(s): *1. Institute for Advanced Study, Princeton, 2. Yale University*

106.35 – Uncovering hidden black holes with extragalactic X-ray surveys

Despite remarkable progress over the past decades, our picture of black hole evolution has remained incomplete due to the challenges of detecting the mysterious "elusive" AGN that are highly obscured or hidden beneath the light of their host galaxies. I will present recent studies by our group and colleagues that use X-ray and multiwavelength extragalactic surveys (particularly with *Chandra*, *NuSTAR*, and *WISE*) to uncover the full population of AGN. Including these elusive AGN in our picture has helped illustrate that AGN accretion is a surprisingly universal, yet highly stochastic process, and has shown that AGN obscuration is linked to processes in galaxy evolution. I will conclude by forecasting the exciting science in this area that will be enabled by future observatories including the *Lynx* concept X-ray mission. This work is supported by the National Science Foundation through grant numbers 1515404 and 1554584, and NASA through grant numbers NNX15AP24G, NNX15AU32H, and NNX16AN48G.

Author(s): Ryan C. Hickox[1]
Institution(s): *1. Dartmouth College*

106.36 – Testing Models of Circum-Binary-AGN Accretion for PSO J334.2028+01.4075

We present analysis of new *Chandra* data of PSO J334.2028+01.4075 (PSO J334 hereafter), a strong binary AGN candidate discovered by Liu et al. (2015) based on periodic variation of the optical flux. Recent radio coverage presented in Mooley et al. (2017) further supports that PSO J334 is a binary black hole system, as the quasar was found to be lobe-dominated with a twisted radio structure, possibly due to a precessing jet. With no prior X-ray coverage for PSO J334, our new 50 ksec *Chandra* observation allows for the unique opportunity to differentiate between a single or binary-AGN system, and if a binary, can characterize the mode of accretion. The two most basic sets of predictions via simulations of circum-binary accretion model are a “cavity”, where the inner region of the accretion disk is mostly empty and emission is truncated blueward of the wavelength associated with the temperature of the innermost ring, or “minidisks”, where there is substantial accretion onto one or both of the members of the binary, each with their own shock-heated thin-disk accretion system. We find the X-ray emission to be well-fit with a heavily absorbed power-law, incompatible with the cavity scenario. Further, we construct an SED of PSO J334 by combining radio through X-ray observations and compare it to standard QSO SEDs. We discuss the implications of the comparison between the SED of PSO J334 and that of a single AGN, and assess the likelihood of the binary model for PSO J334.

Author(s): Adi Foord[1], Kayhan Gultekin[1], Mark Reynolds[1]
Institution(s): *1. University of Michigan*

106.37 – New methods to benchmark simulations of accreting black holes systems against observations

The field of black hole accretion has been significantly advanced by the use of complex ideal general relativistic magnetohydrodynamics (GRMHD) codes, now capable of simulating scales from the event horizon out to ~10^5 gravitational radii at high resolution. The challenge remains how to test these simulations against data, because the self-consistent treatment of radiation is still in its early days, and is complicated by dependence on nonideal/microphysical processes not yet included in the codes. On the other extreme, a variety of phenomenological models (disk, corona, jet, wind) can well-describe spectra or variability signatures in a particular waveband, although often not both. To bring these two methodologies together, we need robust observational "benchmarks" that can be identified and studied in simulations. I will focus on one example of such a benchmark, from recent observational campaigns on black holes across the mass scale: the jet break. I will describe new work attempting to understand what drives this feature by searching for regions that share similar trends in terms of dependence on accretion power or magnetisation. Such methods can allow early tests of simulation assumptions and help pinpoint which regions will dominate the light production, well before full radiative processes are incorporated, and will help guide the interpretation of, e.g. Event Horizon Telescope data.

Author(s): Sera Markoff[1], Koushik Chatterjee[1], Matthew Liska[1], Alexander Tchekhovskoy[2], Casper Hesp[1], Chiara Ceccobello[1], Thomas Russell[1]
Institution(s): *1. University of Amsterdam, 2. University of California, Berkeley*

106.38 – Searches for Angular Extension in High Latitude Fermi-LAT Sources

We report on the Fermi High-Latitude Extended Sources Catalog (FHES), a comprehensive search for spatially extended gamma-ray sources at high Galactic latitudes based on data from the Fermi Large Area Telescope (LAT). While the majority of high-latitude LAT sources are extragalactic blazars that appear point-like within the LAT angular resolution, there are several physics scenarios that predict the existence of populations of spatially extended sources. If Dark Matter (DM) consists of Weakly Interacting Massive Particles, the annihilation or decay of these particles in subhalos of the Milky Way would appear as a population of unassociated gamma-ray sources with finite angular extent. Gamma-ray emission from blazars could also be extended (so-called pair halos) due to the deflection of electron-positron pairs in the intergalactic magnetic field (IGMF). The pairs are produced in the absorption of gamma rays in the intergalactic medium and subsequently up-scatter photons of background radiation fields to gamma-ray energies. Measurement of pair halos could provide constraints on the strength and coherence length scale of the IGMF. We report on new extended source candidates found in the FHES as well as constraints on extended emission from point-like sources and discuss the implications of these results in the context of searches for both DM subhalos and IGMF-induced pair halos.

Author(s): Regina Caputo[4], Mattia Di Mauro[3], Manuel Meyer[3], Matthew Wood[2], Jonathan Biteau[1]
Institution(s): *1. IPN - Univ. Paris Sud - Univ. Paris/Saclay, 2. SLAC/Stanford, 3. Stanford, 4. UMD/NASA/GSFC*

106.39 – *NuSTAR* Observations of Heavily Obscured Quasars Selected by WISE

A key goal of the *Nuclear Spectroscopic Telescope Array* (*NuSTAR*) program is to find and characterize heavily obscured quasars, luminous accreting supermassive black holes hidden by gas and dust. Based on mid-infrared (IR) photometry from *Wide-Field Infrared Survey Explorer* (WISE) and optical photometry from the Sloan Digital Sky Surveys, we have selected a large population of obscured quasars; here we report the *NuSTAR* observations of four WISE-selected heavily obscured quasars for which we have optical spectroscopy from the Southern African Large Telescope and KECK Telescope. Three of four objects are undetected with *NuSTAR*, while the fourth has only a marginal detection. We confirm our objects have observed hard X-ray (10-40 keV) luminosities at or below ~10^{43} erg s^{-1}. We compare IR and X-ray luminosities to obtain estimates of hydrogen column N_H based on the suppression of the hard X-ray emission. We estimate N_H to be at or greater than 10^{25} cm^{-2}, confirming that WISE and optical selection can identify very heavily obscured quasars that may be missed in X-ray surveys.

Author(s): Wei Yan[1]
Institution(s): *1. Dartmouth College*

106.40 – The Effects of Accretion Disk Geometry on AGN Reflection Spectra

Despite being the gravitational engines that power galactic-scale winds and mega parsec-scale jets in active galaxies, black holes are remarkably simple objects, typically being fully described by their angular momenta (spin) and masses. The modelling of AGN X-ray reflection spectra has proven fruitful in estimating the spin of AGN, as well as giving insight into their accretion histories and the properties of plasmas in the strong gravity regime. However, current models make simplifying assumptions about the geometry of the reflecting material in the accretion disk and the irradiating X-ray corona, approximating the disk as an optically thick, infinitely thin disk of material in the orbital plane. We present results from the new relativistic raytracing suite, Fenrir, that explore the effects that disk thickness may have on the reflection spectrum and the accompanying reverberation signatures. Approximating the accretion disk as an optically thick, geometrically thin, radiation pressure dominated disk (Shakura & Sunyaev 1973), one finds that the disk geometry is non-negligible in many cases, with significant changes in the broad Fe K line profile. Finally, we explore the systematic errors inherent in approximating the disk as being infinitely thin when modeling reflection spectrum, potentially biasing determinations of black hole and corona properties.

Author(s): Corbin James Taylor[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland*

106.41 – Nonthermal Particle Acceleration in Magnetic Reconnection

Magnetic reconnection is a leading mechanism for dissipating magnetic energy and accelerating nonthermal particles in Poynting-flux-dominated flows. In this study, we investigate nonthermal particle acceleration during magnetic reconnection in a magnetically dominated plasma using fully kinetic simulations. We have studied the magnetically dominated regime by varying $\sigma_e = 10^3$-10^5 and mass ratios. The results demonstrate that reconnection quickly establishes power-law energy distributions for both electrons and ions within several (2-3) light-crossing times. For the cases with periodic boundary conditions, the power-law index is $1 < p < 2$ for both electrons and ions. We study particle acceleration in magnetic reconnection via large-scale 3D kinetic simulations to examine several effects that may be important, including pre-existing fluctuations, kink and secondary tearing instabilities, and open boundary conditions. The results show that particle acceleration in reconnection layers is surprisingly robust despite the development of 3D turbulence and instabilities. The main acceleration mechanism is a Fermi-like acceleration through the drift motions of charged particles. We discuss the implication of this study in the context of Poynting-flux dominated jets and pulsar winds, especially the applications for explaining nonthermal high-energy emissions.

Author(s): Fan Guo[1], Hui Li[1], Haocheng Zhang[1], William Daughton[1], Yi-Hsin Liu[2], Nicole Lloyd-Ronning[1]
Institution(s): *1. Los Alamos National Laboratory, 2. NASA Goddard Space Flight Center*

106.42 – X-ray Normal, Optically Bright Galaxies in the Chandra Deep Field South

Absorbed active galactic nuclei (AGNs) represent the dominant class of extragalactic sources in deep hard X-ray surveys. However, their true nature is often unclear because of ambiguities in their optical spectra. As a result, several important questions concerning the diversity and cosmic evolution of the AGN population remain unanswered. To explore the possibility of evolution, we have analyzed the multiwavelength properties of nearby absorbed AGNs and their host galaxies in a way that facilitates a direct, meaningful comparison to distant absorbed AGNs detected in the Chandra Deep Field South (CDF-S). Specifically, we have assembled the integrated spectral energy distributions (SEDs) of (a) a large, unbiased sample of nearby Seyfert 2 galaxies and (b) a set of carefully selected absorbed AGNs from the CDF-S, many of which are classified as XBONGs (X-ray–bright, optically normal galaxies) due to their starlight-dominated optical spectra. Comparisons of the SEDs have been carried out in a manner that properly accounts for redshift effects and the way in which the intrinsic luminosity function is sampled in a flux-limited pencil-beam survey like the CDF-S. In general, the SEDs of nearby Seyfert 2s provide a good match to the SEDs of distant absorbed AGNs. However, while the X-ray luminosities of "optically normal" galaxies in the CDF-S are comparable to those of local Seyfert 2s, their stellar continuum luminosities are often much higher than those of the nearby objects. Thus, distant XBONGs are perhaps best characterized as XNOBGs: X-ray normal, optically bright galaxies. It is likely that their optical spectra suffer from severe host-galaxy dilution, which provides a natural explanation for their normal appearance.

Author(s): Edward C. Moran[1]
Institution(s): *1. Wesleyan Univ.*

106.43 – Extremely Variable Quasars from CRTS and WISE

I will present deep dives on a few examples of highly variable quasars identified from the Catalina Real-Time Transient Survey (CRTS) and WISE/NEOWISE. In particular, I will focus on a CRTS-identified iron low-ionization broad absorption line (FeLoBAL) quasar which, over the past decade, has transformed into a more typical BAL quasar (Stern et al. 2017) and a WISE-identified quasar that has shut off in the past decade (Stern et al., in prep.). I will focus on what we learn about the physics of these systems from the multiwavelength imaging and spectroscopy. Given the pace of discovery, additional interesting examples are expected to be discovered before the conference.

Author(s): Daniel Stern[1]
Institution(s): *1. JPL/ Caltech*

106.44 – Observing the Fast X-ray Spectral Variability of NLS1 1H1934-063 with XMM-Newton and NuSTAR

The most variable active galactic nuclei (AGN), taken together, are a compelling wellspring of interesting accretion-related phenomena. They can exhibit dramatic variability in the X-ray band on a range of timescales down to a few minutes. We present the exemplifying case study of 1H1934-063 ($z = 0.0102$), a narrow-line Seyfert I (NLS1) that is among the most variable AGN ever observed with XMM-Newton. We present spectral and temporal analyses of a concurrent XMM-Newton and NuSTAR observation taken in 2015 and lasting 120 ks, during which the source exhibited a steep (factor of 1.5) plummet and subsequent full recovery of flux that we explore in detail here. Combined spectral and timing results point to a dramatic change in the continuum on timescales as short as a few ks. Similar to other highly variable Seyfert 1s, this AGN is quite X-ray bright and displays strong reflection spectral features. We find agreement with a change in the continuum, and we rule out absorption as the cause for this dramatic variability observed even at NuSTAR energies. We compare detailed time-resolved spectral fitting with Fourier-based timing analysis in order to constrain coronal geometry, dynamics, and emission/absorption processes dictating the nature of this variability. We also announce the discovery of a Fe-K time lag between the hard X-ray continuum emission (1 - 4 keV) and its relativistically-blurred reflection off the inner accretion flow (0.3 - 1 keV).

Author(s): Sara Frederick[1], Erin Kara[1], Christopher S. Reynolds[1]

Institution(s): *1. University of Maryland College Park*

106.45 – The BAT AGN Spectroscopic Survey (BASS)

We present the Swift BAT AGN Spectroscopic Survey (BASS) and discus the first four papers. The catalog represents an unprecedented census of hard-X-ray selected AGN in the local universe, with ~90% of sources at z<0.2. Starting from an all-sky catalog of AGN detected based on their 14-195 keV flux from the 70-month Swift/BAT catalog, we analyze a total of 1279 optical spectra, taken from twelve different telescopes, for a total of 642 spectra of unique AGN. We present the absorption and emission line measurements as well as black hole masses and accretion rates for the majority of obscured and un-obscured AGN (473), representing more than a factor of 10 increase from past studies. Consistent with previous surveys, we find an increase in the fraction of un-obscured (type 1) AGN, as measured from broad Hbeta and Halpha, with increasing 14-195 keV and 2-10 keV luminosity. We find the FWHM of the emission lines to show broad agreement with the X-ray obscuration measurements. Compared to narrow line AGN in the SDSS, the X-ray selected AGN in our sample with emission lines have a larger fraction of dustier galaxies suggesting these types of galaxies are missed in optical AGN surveys using emission line diagnostics.

Author(s): Michael Koss[1]
Institution(s): *1. Eureka Scientific*

107 – ISM & Galaxies Poster Session

107.01 – HIgh-Latitude Neutral Hydrogen Shells identified in GALFA-HI

Supernovae and stellar winds are important processes in the development and evolution of galaxies. Due to these effects in generations of stars, the interstellar medium (ISM) is turbulent, multiphase, and filled with complex interacting structures. HI (neutral hydrogen) shells are formed when hot, expanding bubbles sweep up shells of neutral material. These shells gradually cool, slow down, and mix with the surrounding interstellar material, but we still lack a complete, detailed picture of the physical state and evolution of gas in our Galaxy's ISM. Studies of numerous shells at different stages of evolution are needed, but biases in search techniques and limitations of data quality and coverage have hindered our efforts. The Galactic Arecibo L-band Feed Array (GALFA) 21-cm survey of the Arecibo sky provides have uniquely high angular resolution except within a few degrees of the Galactic plane. A visual search of these data can therefore identify new structures with small angular diameter at high Galactic latitudes, at all stages of evolution. We present the results of a partial search of these data, focusing on high Galactic latitudes. For each potential shell, the location, velocity, angular size, and velocity range were determined, as well as estimates of the shell wall completeness and persistence of shell completeness, shape, and location across its velocity range. To date, we have identified over 100 potential new shells, ranging in size from 0.1 to 4.5 degrees. Approximately 2/3 of these are smaller than 2 degrees in diameter, a size range that was significantly underrepresented in previous searches. The statistical properties of these newly found shells will be presented, along with details on selected examples.

Author(s): Shauna Sallmen[4], Rebecca Taylor[4], Eric J. Korpela[2], Joshua Eli Goldston Peek[1], Brian Babler[3]
Institution(s): *1. Space Telescope Science Institute, 2. UC Berkeley, 3. Univ. of Wisconsin - Madison, 4. Univ. of Wisconsin - La Crosse*

107.03 – Where in the Milky Way is the North Polar Spur?

The true nature of the North Polar Spur (NPS) is obscured by our lack of information about its distance. It has been variously modeled as a nearby superbubble and the nuclear outflow from the Galaxy. Although the feature extends from the Galactic plane to b=85, and different parts may be at different distances, recent attention has focused on the base of the NPS and a possible connection to the Fermi bubbles. We have acquired a continuous mosiac of XMM observations covering the southern end of the NPS in order to determine whether the emission is absorption bounded or emission bounded. Our initial result is that the emission is absorption bounded and the bulk of the emission is must be further away than 300 pc. We present here a more subtle analysis of the same data, using new ESAS tools, to determine how much of the emission might be local.

Author(s): K. D. Kuntz[2], Rosine Lallement[3], Steven L. Snowden[1]
Institution(s): *1. Goddard Space Flight Center, 2. Johns Hopkins Univ., 3. Observatoire Paris-Meudon*

107.04 – The Star-Formation History Dependence of X-ray Binary Formation: Clues from M51

Recently, we have found, in the Chandra Deep Field-South, that the emission from X-ray binary (XRB) populations in galaxies evolves significantly with cosmic time, most likely due to changes in the physical properties of galaxies like star-formation rate, stellar mass, stellar age, and metallicity. However, it has been challenging to directly show that these same physical properties are connected to XRB populations using data from nearby galaxies. We present a new technique for empirically calibrating how X-ray binary (XRB) populations evolve following their formation in a variety of environments. We first utilize detailed spectral energy distribution modeling of far-UV to far-IR broadband data of the nearby (~8.5 Mpc) face-on spiral galaxies M51 to construct a map of its star-formation history (SFH) on subgalactic scales. Using Chandra data, we then identify the locations of the XRBs and correlate their formation frequencies with local SFH, as characterized by the mean mass-weighted stellar age. In this talk, I will show promising first constraints on how the shape and normalization of XRB luminosity function evolves with time based on our analysis. I further discuss how expanding our sample to an archival sample of ~25 face-on spirals will lead to a detailed empirical timeline for how XRBs form and evolve in a variety of environments and throughout cosmic time.

Author(s): Bret Lehmer[6], Rafael T. Eufrasio[6], Andreas Zezas[5], Antara Basu-Zych[3], Tassos Fragos[1], Ann E. Hornschemeier[3], Vassiliki Kalogera[4], Andrew Ptak[3], Panayiotis Tzanavaris[3], Mihoko Yukita[2]
Institution(s): *1. Geneva Observatory, 2. Johns Hopkins University, 3. NASA GSFC, 4. Northwestern, 5. SAO, 6. Univ of Arkansas*

107.05 – Impact of Cosmic Ray Transport on Galactic Winds

Despite playing a fundamental role in galaxy evolution, the physical mechanisms responsible for driving galactic winds remain unclear. The role of cosmic rays generated by supernovae and young stars has very recently begun to receive significant attention due to the realization that cosmic rays can efficiently accelerate galactic winds. Microscopic cosmic ray transport processes are fundamental for determining the efficiency of cosmic ray wind driving. Previous studies focused on modeling of cosmic ray transport either via constant diffusion coefficient or via streaming proportional to the Alfv{\'e}n speed. However, in predominantly neutral gas, cosmic rays can propagate faster than in the ionized medium and the effective transport can be substantially larger, i.e., cosmic rays are decoupled from the gas. We perform three-dimensional magneto-hydrodynamical simulations of patches of galactic disks including the effects of cosmic rays. Our simulations include the decoupling of cosmic rays in the neutral ISM phases. We find that, compared to the ordinary diffusive cosmic ray transport case, accounting for the decoupling leads to significantly different wind properties such as the cosmic ray spatial distribution, wind speed, density, and temperature. These results have implications for the magnetization of the circumgalactic medium and the pollution of the circumgalactic medium with cosmic rays.

Author(s): Ryan Farber[2], Mateusz Ruszkowski[2], Hsiang-Yi Karen Yang[1], Ellen Gould Zweibel[3]
Institution(s): *1. University of Maryland, College Park, 2. University of Michigan, Ann Arbor, 3. University of Wisconsin-Madison*

107.06 – The Origin of the Hot Gas Around NGC 891

Galaxies that are Milky Way-sized or larger are surrounded by extended halos of million-degree gas that may contain about as much mass as the optical disk. This gas is a combination of material expelled by feedback and accreted intergalactic gas, which is heated by an accretion shock to the virial temperature, but the fraction of each remains unknown. We report on a 350 ks XMM-Newton observation of NGC 891, a nearby, edge-on Milky Way analog with a bright X-ray halo. The data strongly suggest that most of the hot gas is intergalactic in origin, and they also reveal what is likely an old nuclear superwind, extending at least 15 kpc above the disk on one side. Since NGC 891 also has a star formation rate of about 4 solar masses per year, this suggests that the galactic fountain of supernovae carries a lot of energy but little hot mass.

Author(s): Edmund J. Hodges-Kluck[1], Joel N. Bregman[1], Jiang-Tao Li[1]
Institution(s): *1. University of Michigan*

107.07 – Hot X-ray Coronae around Spiral Galaxies: A Unique Probe of Galaxy Formation Models

The presence of hot gaseous coronae in the dark matter halos of massive spiral galaxies is a fundamental prediction of all galaxy formation models. Yet these coronae remained unexplored for several decades, thereby posing a serious challenge to observers and theorists. Recently, a major breakthrough has been made, and several X-ray coronae have been detected around massive spiral galaxies. We have studied the properties of these luminous X-ray coronae in detail and confronted their observed properties with results of the hydrodynamical galaxy formation simulation, Illustris. This comparison pointed out that the properties of these coronae are extremely sensitive to the incorporated physics in the simulations, and hence observations of X-ray coronae provide a powerful method to constrain the physical processes (e.g. stellar and AGN feedback and metal enrichment) that play an essential role in forming galaxies from the early Universe to the present epoch. I will overview the key observational results, discuss the comparison between observations and simulations, and highlight the future prospects of further exploring hot coronae around spiral galaxies.

Author(s): Akos Bogdan[3], Florence Concepcion Mairey[3], Herve Bourdin[3], William R. Forman[3], Ralph P. Kraft[3], Mark Vogelsberger[2], Lars E. Hernquist[1], Christine Jones[3]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Massachusetts Institute of Technology, 3. Smithsonian Astrophysical Observatory*

107.08 – Chandra Early Type Galaxy Atals

The hot gas in early type galaxies (ETGs) plays a crucial role in understanding their formation and evolution. As the hot gas is often extended to the outskirts beyond the optical size, the large scale structural features identified by Chandra (including jets, cavities, cold fronts, filaments and tails) point to key evolutionary mechanisms, e.g., AGN feedback, merging history, accretion, stripping and star formation and its quenching. We have systematically analyzed the archival Chandra data of ~100 ETGs to study the hot ISM. We produce the uniformly derived data products with spatially resolved spectral information and will make them accessible via a public web site. With 2D spectral infomation, we further discuss gas morphology, scaling relations, X-ray based mass profiles and their implications related to various physical mechanisms (e.g., stellar and AGN feedback).

Author(s): Dong-Woo Kim[1], Craig Anderson[1], Douglas J. Burke[1], Giuseppina Fabbiano[1], Antonella Fruscione[1], Jennifer Lauer[1], Michael McCollough[1], Douglas Morgan[1], Amy Mossman[1], Ewan O'Sullivan[1], Alessandro Paggi[1], Saeqa Dil Vrtilek[1], Ginevra Trinchieri[2]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. INAF*

107.09 – Basic Properties of UV Halos within 75 Mpc

Extraplanar dust around highly inclined, star-forming galaxies produces extragalactic reflection nebulae, which are most easily visible as diffuse ultraviolet halos. Using moderately deep Swift-UVOT and GALEX data, we showed that these halos exist around a small sample of galaxies within 25 Mpc. Here, we report on an effort to search for halos around highly inclined, star-forming galaxies within ~75 Mpc, with stellar masses greater than about 1e10 solar masses, and which have sufficient GALEX or Swift data. We describe the detection method and present a correlation analysis between UV halo and galaxy properties in various subsamples, which suggests that many, if not most, galaxies have at least 1 million solar masses of extraplanar dust within 10 kpc of the disk. The typical dust-to-gas ratio suggests that this dust traces about 1e8 solar masses of material expelled from the disk.

Author(s): Edmund J. Hodges-Kluck[1], Joel N. Bregman[1], Chris HyunJoong Lee[1]
Institution(s): *1. University of Michigan*

107.10 – Detection of possible intervening Mg X associated with A hot gaseous galaxy halo

Galaxies may store a significant fraction of baryonic material in their hot halos, which can be traced by high ionization absorption systems in spectra of background QSOs. A hot halo of an L* galaxy has a virial temperature ~ 10^6 K, corresponding to the peak ionization fraction for Mg X. We discovered a Mg X absorption system, in the sightline towards LBQS 1435-0134, which also contains Ne VIII, Ne VI, O VI, Ne V, O V, Ne IV, O IV, N IV, O III, and H I. Further modeling shows that the highest ionization state ions, Mg X and Ne VIII, cannot be produced by the photoionization model. A collisional ionization model can reproduce the observations, and all of the ions can be accommodated in a three- temperature plasma or one gas with a power-law temperature distribution, dN / dT = 10^(4.4 +- 2.2 - [Z/X]) T^(1.55 +- 0.41) (for 10^(4.39 +- 0.13) K < T < 10^(6.04+-0.05) K). In the power-law temperature model, the total hydrogen column density is 8.2 * 10^19(0.3 Zsun/Z), and most of the gaseous mass is in the hot phase with the postive power index. The modeling results show that the gas is consistent with a hot volume-filled gaseous galaxy halo (N(H) <~ 10^20 cm^-2 and T ~ 10^6 K), which contains a baryonic mass that may be comparable or greater than the stellar mass (~10^11Msun assuming n200).

Author(s): Zhijie Qu[1], Joel N. Bregman[1]
Institution(s): *1. University of Michigan, Ann Arbor*

107.11 – Dust in Extragalactic Reflection Nebulae

Observational evidence for extragalactic dust has been recently found in the form of UV extragalactic reflection nebulae around edge-on spiral galaxies, but the nature of the dust is largely unknown. To derive dust parameters, UV fluxes from the spacecrafts *GALEX* and *Swift* have been compared with model UV halo SEDs, which have been created from galaxy template spectra and a silicate-graphite dust model. The model contains two free parameters, which are fractional composition and maximum grain size. These analyses have been done for a sample of 8 nearby edge-on spiral galaxies with bright UV halos, where the dust properties can be spatially resolved, such as inside and outside of galactic winds or as a function of height from the galactic disc. The dust properties give insight into how dust is expelled from the galactic disc, which can also be applied to understanding gaseous outflows from the galaxies as well.

Author(s): Chris H. Lee[1], Edmund J. Hodges-Kluck[1]
Institution(s): *1. University of Michigan*

107.12 – Dissecting Diffuse X-ray Emission in 30 Doradus with T-ReX

30 Doradus (the Tarantula Nebula) offers us a microscope on starburst astrophysics, having endured 25 Myrs of the birth and death of the most massive stars known. Across 30 Dor's 250-pc extent, stellar winds and supernovae have carved its ISM into an amazing display of arcs, pillars, and bubbles. For over 40 years, we have also known that 30 Dor is a bright X-ray emitter, so its familiar stars and cold ISM structures suffer irradiation by multi-million-degree plasmas. The 2-Ms Chandra X-ray Visionary Project ``The Tarantula -- Revealed by X-rays'' (T-ReX) exploits Chandra's fine spatial resolution and the ACIS-I field of view to study ISM interfaces on 1--10 pc scales across the entire 30 Dor complex. Here we give preliminary results from ongoing analyses of these data, focusing on the diffuse X-ray emission. Massive star winds and cavity supernovae over the millenia have contributed to a broad mix of X-ray-

emitting plasmas and absorbing columns, showing that 30 Dor's hot ISM is just as complex and confusing as that seen at colder temperatures.

Author(s): Leisa K. Townsley[1], Patrick Broos[1]
Institution(s): *1. Penn State Univ.*

107.13 – T-ReX Spies the Stars of 30 Doradus

30 Doradus (the Tarantula Nebula) is the Local Group's most massive young star-forming complex. At its heart is R136, the most massive resolved stellar cluster; R136 contains, in turn, the most massive stars known. The Chandra X-ray Observatory has recently observed 30 Dor for the 2-megasecond X-ray Visionary Project ``The Tarantula -- Revealed by X-rays'' (T-ReX). This deep observation exploits Chandra's fine spatial resolution to study the full complement of massive stars and the brightest pre-main sequence stars that trace 25 Myrs of star formation in this incomparable nearby starburst. Here we give preliminary results from the ongoing analyses of the data, focusing on the massive stars. While many remain undetected even in this deep ACIS-I observation, a few show dramatic X-ray lightcurves and/or high luminosities befitting this amazing starburst cluster.

Author(s): Patrick Broos[1], Leisa K. Townsley[1], Andrew Pollock[2], Paul Crowther[2]
Institution(s): *1. Penn State University, 2. University of Sheffield*

107.14 – The formation efficiency of X-ray binaries: insights from nearby galaxies

The formation efficiency of X-ray binaries (XRBs) is a key parameter for constraining their formation and evolution channels and for modeling the X-ray emission of galaxies at cosmological distances. We present results from our direct measurement of the formation efficiency of XRBs associated with young stellar populations in the Magellanic Clouds. More specifically, we find that the formation efficiency of XRBs in the SMC peaks at ages between 20-50Myr. On the other hand, the formation efficiency of XRBs associated with stellar populations in the 6-25Myr age range in the higher metallicity LMC is ~17 times lower than that in the SMC in the same age range. We compare these results with measurements of the formation efficiency of young XRBs in other nearby galaxies (e.g M81) and we discuss them in the context of XRB population synthesis models.

Author(s): Andreas Zezas[1], Vallia Antoniou[1], JaeSub Hong[1], Jeremy J. Drake[1], Paul Sell[2], Jeffrey Andrews[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Univ, of Crete / FORTH*

107.15 – A Chandra Archival Survey of the X-ray Source Populations of Nearby Galaxies

We present results of a volume-limited Chandra archival survey of the X-ray point sources populations of nearby galaxies. We define our sample to include all observations of at least 5 ks of any galaxy within 15 Mpc. The complete sample is in excess of 15000 individual point sources, approximately half of which are contained with the D25 ellipses of galaxies. We present spectral and temporal analyses of this sample, from which we can cleanly define the parameter spaces in color, variability, and luminosity occupied by different classes of sources (e.g., LMXBs vs. HMXBs). For all sources, we perform detailed spatial modeling, spectral fitting, multiband X-ray photometry, and multimodal timing analyses. We further discuss source classes as a function of host galaxy morphology, star formation rate, stellar mass distribution, optical extent, interaction history, and metallicity. Finally, we discuss incompleteness in the sample, and what observations can be conducted in the following years to fill the gap.

Author(s): Roy E. Kilgard[1], Simon Wright[1], Gloria Fonseca[1], Anthony Santini[1], Hannah Fritze[1]
Institution(s): *1. Wesleyan Univ.*

107.16 – X-ray Spectroscopy of the Andromeda Galaxy's Nuclear Feedback

The central region of the Andromeda galaxy (M31) is currently quiescent in both AGN and star formation, but shows strong indications for recent AGN activity. The X-ray grating spectra from the XMM-Newton observations show enhanced forbidden lines of He-like Oxygen, Neon, and Nitrogen Kalpha triplets, as well as signatures for multi-temperature diffuse hot gas. We find that these results can be well interpreted by an AGN-relic model, which we have developed, suggesting that the galaxy was a bright AGN about half a million years ago. This study demonstrates the power of the X-ray spectroscopy, which will be greatly improved by upcoming X-ray missions, in revealing the recurrence history of AGN and the galaxy feedback in general.

Author(s): Shuinai Zhang[3], Daniel Wang[4], Adam Foster[1], Li Ji[3], Zhiyuan Li[2], Wei Sun[3], Shuiyao Huang[4]
Institution(s): *1. CfA, 2. NJU, 3. Purple Mountain Observatory, 4. UMASS*

107.17 – Exploring the gaseous coronae of galaxies using absorption studies

Galaxy formation models predict the existence of gaseous coronae in dark matter halos around galaxies, which coronae extend to large radii. For massive galaxies the shock-heated gas may emit in the X-ray regime. Due to its long cooling time, the dominant fraction of the large-scale gas remains quasi-static, and should be observable at the present epoch. However, the overall characteristics of these coronae are poorly understood. Although hot gaseous halos were explored around a handful of massive spiral galaxies, these observations explore the coronae only out to about 15% of the virial radius. Therefore, these individual observations shed light only on a few percent of the total gas mass in the corona, while most of the gas remains unexplored. A promising approach to probe the outer parts of the halos is to perform absorption studies. The strongest transitions from the hot gas are expected from the O VII, C V, and Ne IX ions. In this work we utilize Chandra LETG and XMM-Newton RGS observations along with the known redshift of foreground absorption line systems to carry out a systematic study of luminous background quasars. The goal of this study is to identify absorption lines that may originate from the gaseous coronae of foreground galaxies, which could play a key role in understanding the characteristics of the hot gaseous coronae.

Author(s): Orsolya Kovacs[1], Akos Bogdan[1], Ralph P. Kraft[1], Randall K. Smith[1], William R. Forman[1]
Institution(s): *1. Smithsonian Astrophysical Observatory*

107.18 – Simulating 3D Stellar Winds and Diffuse X-ray Emissions from Gases in Non-equilibrium Ionization State

We investigate the physical properties of stellar winds launched in super stellar clusters (SSCs). Chandra observations have detected the presence of diffuse X-ray emission caused by hot gas from such winds in SSCs, and provide the best probe for understanding interactions between the stellar winds and the complex nursery regions. However, the details of the origin of cluster winds, the mass and energy ejection, the formation of diffuse X-ray emission, the fraction of winds contribution to the distribution of diffuse X-ray emission still remain unclear. We developed a multiphysics hydrodynamic model including self-gravity, head conduction and performed 3D simulations with an unprecedented grid resolution due to adaptive mesh refinement (AMR) capability in a case study of NGC 3603, as a supplement to the analysis of the archived 500 ks Chandra observations. The synthetic emission will be computed by assuming the gas in a non-equilibrium ionization (NEI) state indicated by Chandra observation, not coronal ionization equilibrium (CIE) that most works assumed, by using a customized NEI calculation module based on AtomDB. The results will be compared to the Chandra observations.

Author(s): Min Long[1], Wei Sun[2], Shu Niu[2], Xin Zhou[2], Li Ji[2]
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107.19 – Snapshots in X-ray binary evolution: Using HAEs and post-starburst galaxies to study the time-dependence of XRB populations

The X-ray emission in galaxies, due to X-ray binaries (XRBs), appears to depend on global galaxy properties such as stellar mass (M_*), star formation rate (SFR), metallicity, and stellar age. This poster will present unique galaxy populations with well-defined stellar ages to test current relations and models. Specifically, H-alpha emitters, which are nearby analogs of galaxies in the early universe, trace how XRBs form and evolve in young, metal-poor environments. Post-starburst galaxies, selected by the strength of the H-delta equivalent width, probe the XRBs related to stellar ages of 0.1-1 Gyr. Together, these samples offer important constraints for the evolution of XRBs with stellar age.

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108 – Stellar Compact Poster Session

108.01 – X-ray Emission Properties of Intermediate-Mass, Pre-Main-Sequence Stars

Intermediate-mass (2–8 $M_\odot$) main-sequence stars with A to mid-B spectral types occupy an X-ray "desert" of weak intrinsic emission between low- and high-mass stars. Lacking the wind-shock driven emission of massive, O and early B stars or the convectively-driven magnetic reconnection flaring activity of later-type stars, X-ray detections of (non-peculiar) main-sequence AB stars are typically ascribed to the presence of unresolved, lower-mass binary companions. There is mounting evidence, however, that intermediate-mass, pre-main sequence stars (IMPS) with GK spectral types produce intrinsic X-ray emission that rapidly decays with time following the development of a radiative zone as IMPS approach the ZAMS as AB stars. This suggests that X-ray emission from IMPS may be a more luminous analog of the well-studied coronal X-ray emission from lower-mass, T Tauri stars. Statistical studies of young IMPS have been hampered by their scarcety in nearby, unobscured star-forming regions. We present the first results from a spectral-fitting study to measure absorption-corrected X-ray luminosities and plasma temperatures for hundreds of candidate X-ray emitting IMPS found in the MYStIX and MAGiX surveys of massive Galactic star forming regions. Candidate IMPS are placed on the HR diagram via a novel infrared spectral energy distribution modeling technique designed for highly-obscured, young massive star-forming regions. The rapid decay of X-ray emission from these objects has the potential to provide an independent chronometer to constrain star formation rates, and may produce an age-dependent bias in the relationship between the stellar X-ray luminosity function and mass function in distant (>2 kpc) regions observed with relatively shallow X-ray observations.

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108.02 – Suppression of CMEs on active stars by overlying magnetic field

On the Sun, the association rate of flares with coronal mass ejections (CMEs) increases with flare energy such that energetic X-class flares are nearly all associated with CMEs. Flares on active stars are commonly orders of magnitude more energetic than their solar counterparts, and extrapolating the solar trend suggests that all the flares we observe on active stars should be associated with CMEs. Such an association can imply uncomfortably high CME mass loss rates of more than 10^-11 Msun/yr for the most active stars. We suggest that, instead, only the more energetic CMEs escape and most are suppressed by strong overlying magnetic field. Here, we investigate the suppression threshold and its implications for CME rates and mass loss on active stars.

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108.03 – Swift X-ray monitoring of stellar coronal variability

We used California Planet Search Ca II H and K core emission measurements to identify and characterize chromospheric activity cycles in a sample of main-sequence FGK stars. About a dozen of these with existing ROSAT archival data were targeted with Swift to obtain a current epoch X-ray flux. We find that coronal variability by a factor of several is common on decade-long timescales (we attempt to link to the chromospheric cycle phase) but can also occur on short timescales between Swift visits to a given target, presumably related to stellar rotation and coronal inhomogeneity or to small flares.

Additionally, we present new Swift monitoring observations of two M dwarfs with known exoplanets: GJ 15A and GJ 674. GJ 15A b is around 5.3 Earth masses with an 11.4 day orbital period, while GJ 674 is around 11.1 Earth masses with a 4.7 day orbital period. GJ 15A was observed several times in late 2014 and then monitored at approximately weekly intervals for several months in early 2016, for a total exposure of 18 ks. GJ 674 was monitored at approximately weekly intervals for most of 2016, for a total exposure of 40 ks. We provide light curves and hardness ratios for both sources, and also compare to earlier archival X-ray data. Both sources show significant X-ray variability, including between consecutive observations. We quantify the energy distribution for coronal flaring, and compare to optical results for M dwarfs from Kepler. Finally, we discuss the implications of M dwarf coronal activity for exoplanets orbiting within the nominal habitable zone.

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108.04 – The 2014 X-Ray Minimum of η Carinae as Seen by *Swift*

We report on Swift X-ray Telescope observations of Eta Carinae (η Car), an extremely massive, long-period, highly eccentric binary obtained during the 2014.6 X-ray minimum/periastron passage. These observations show that η Car may have been particularly bright in X-rays going into the X-ray minimum state, while the duration of the 2014 X-ray minimum was intermediate between the extended minima seen in 1998.0 and 2003.5 by Rossi X-Ray Timing Explorer (RXTE), and the shorter minimum in 2009.0. The hardness ratios derived from the Swift observations showed a relatively smooth increase to a peak value occurring 40.5 days after the start of the X-ray minimum, though these observations cannot reliably measure the X-ray hardness during the deepest part of the X-ray minimum when contamination by the "central constant emission" component is significant. By comparing the timings of the RXTE and Swift observations near the X-ray minima, we derive an updated X-ray period of $P_x = 2023.7 \pm 0.7$ days, in good agreement with periods derived from observations at other wavelengths, and we compare the X-ray changes with variations in the He ii 4686 emission. The middle of the "Deep Minimum" interval, as defined by the Swift column density variations, is in good agreement with the time of periastron passage derived from the He II λ4686 line variations.

Author(s): Michael F. Corcoran[5], Jamar Liburd[1], David C. Morris[9], Christopher Michael Post Russell[3], Kenji Hamaguchi[3], Theodore R. Gull[3], Thomas Madura[4], Mairan Teodoro[3], Anthony F. J. Moffat[7], Noel Richardson[10], Desmond John Hillier[8], Augusto Damineli[2], Jose Groh[6]
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108.05 – Discovery of Rapid X-ray Color Variations from the Enigmatic Be Star, gamma Cassiopeiae

Gamma Cassiopeiae is an enigmatic Be star with unusually hard, strong X-ray emission compared with normal main-sequence B stars. The X-ray origin is controversial between two hypotheses - mass accretion onto a hidden compact companion or a magnetic dynamo driven by the star-Be disk differential rotation. No conclusive evidence, such as an X-ray pulse or magnetic field, has been detected from the star.

We discovered multiple rapid X-ray color variations from gamma Cas during the Suzaku and XMM-Newton observations. These events, which we call ``softness dips", are characterized by symmetric decreases and increases in the softness ratios, and many of them show flat bottoms apparently due to saturation. The softness dip spectra observed during the Suzaku observation (Hamaguchi et al., 2016, ApJ, 832, 140) are best described by either ~40% or ~70% partial covering absorption to kT ~12 keV plasma emission by matter with NH ~2-8e21 cm-2, while the spectrum outside of these dips is almost free of absorption. The XMM-Newton observations find similar dip events. However, one XMM-Newton observation witnesses a strongly absorbed (NH ~2.7e21 cm-2), multiple dip event with almost full soft X-ray covering, indicating the presence of only a few discrete X-ray emitting spots. These results strongly suggest that the X-ray emission originates from mass accretion onto a compact companion. The thermal X-ray nature favors a white dwarf companion, but the formation of a Be-WD binary requires the least understood mass transfer process between two massive stars. We discuss the implications of this result to the stellar evolution mechanism.

Author(s): Kenji Hamaguchi[3], Lidia Oskinova[6], Christopher Michael Post Russell[3], Robert Petre[3], Teruaki Enoto[2], Kumiko Morihana[4], Manabu Ishida[1], Lucas Tax[5], Austin Kim[5]
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108.06 – The Accretion Disk and the Boundary Layer of the Symbiotic Recurrent Nova T Corona Borealis

T Corona Borealis is one of four known Galactic recurrent symbiotic novae, red giant-white dwarf binaries from which multiple thermonuclear runaway (TNR) events, or nova eruptions, have been observed. TNR requires high pressure at the base of the accreted envelope, and a recurrence time of less than a century almost certainly requires both high white dwarf mass and high accretion rate. The eruptions of T CrB were observed in 1866 and 1946; if the 80 year interval is typical, the next eruption would be expected within the next decade or two. Optical observations show that T CrB has entered a super-active state starting in 2015, similar to that seen in 1938, 8 years before the last eruption. In quiescence, T CrB is a known, bright hard X-ray source that has been detected in the *Swift*/BAT all-sky survey. Here we present the result of our *NuSTAR* observation of T CrB in 2015, when it had started to brighten but had not yet reached the peak of the super-active state. We were able to fit the spectrum with an absorbed cooling flow model with reflection, with a reflection amplitude of 1.0. We also present recent *Swift* and *XMM-Newton* observations during the peak of the super-active state, when T CrB had faded dramatically in the BAT band. T CrB is found to be much more luminous in the UV, while the X-ray spectrum became complex including a soft, optically thick component. We present our interpretation of the overall variability as due to instability of a large disk, and of the X-rays as due to emission from the boundary layer. In our view, the *NuSTAR* observation was performed when the boundary layer was optically thin, and the reflection was only from the white dwarf surface that subtended 2π steradian of the sky as seen from the emission region. With these assumptions, we infer the white dwarf in the T CrB system to have a mass of ~1.2 M_{sun}. During the very active state, the boundary layer had turned partially optically thick and produced the soft X-ray component, while drastically reducing the hard X-ray luminosity. We will discuss the implication of variable accretion on the total mass accumulated since the last eruption.

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108.07 – M31N 2008-12a: The Remarkable Recurrent Nova in the Andromeda Galaxy

The recurrent nova M31N 2008-12a in M31 has the shortest interoutburst time of any known recurrent nova. Since its discovery in December 2008 by two Japanese amateur astronomers, Koichi Nishiyama and Fujio Kabashima, a total of 8 subsequent outbursts have been observed. The mean time between observed eruptions (all observed between late August and December) is 364+/-52 days. M31 is close to the sun in March through May, so it is likely that any eruptions that may have occurred during this period have been missed and the recurrence period could be as short as 6 months. Models of thermonuclear runaways on white dwarfs show that only near Chandrasekhar mass white dwarfs accreting at a few times 10^{-7} solar masses per year can produce nova outbursts with a recurrence time of a year, or less. Furthermore, the models show that during the interval between each nova event the accreted mass is expected to be greater than the expelled mass. The white dwarf mass must therefore be growing, and is predicted to reach the Chandrasekhar mass in of order 500,000 years. Thus, M31N 2008-12a is destined either to become a Type Ia supernova (if the white dwarf has a CO composition) or to form a neutron star in an accretion-induced collapse (if the white dwarf has an ONe composition). In this poster, I will describe the latest observations of this fascinating nova.

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108.08 – Super-Spinning Compact Objects and Rapid Variability of Galactic Microquasars

In our previous work we applied several models of high-frequency quasi-periodic oscillations to estimate the spin of the central compact object in three Galactic microquasars. We also assumed the possibility that the central compact body is a super-spinning object. Here we extend our consideration and investigate in a consistent way the implications of several resonance models so far discussed only in the context of black holes.

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108.09 – Diverse Long-Term Variability of Five Candidate High-Mass X-ray Binaries from *Swift* Burst Alert Telescope Observations

We present an investigation of long-term modulation in the X-ray light curves of five little-studied candidate high-mass X-ray binaries using the *Swift* Burst Alert Telescope. IGR J14488-5942 and AX J1700.2-4220 show strong modulation at periods of 49.6 and 44 days, respectively, which are interpreted as orbital periods of Be star systems. For IGR J14488-5942, observations with *Swift* X-ray Telescope show a hint of pulsations at 33.4 s. For AX J1700.2-4220, 54 s pulsations were previously found with *XMM-Newton*. Swift J1816.7-1613 exhibits complicated behavior. The strongest peak in the power spectrum is at a period near 150 days, but this conflicts with a determination of a period of 118.5 days by La Parola et al. (2014). AX J1820.5-1434 has been proposed to exhibit modulation near 54 days, but the extended BAT observations suggest modulation at slightly longer than double this at approximately 111 days. There appears to be a long-term change in the shape of the modulation near 111 days, which may explain the apparent discrepancy. The X-ray pulsar XTE J1906+090, which was previously proposed to be a Be star system with an orbital period of ~30 days from pulse timing, shows peaks in the power spectrum at 81 and 173 days. The origins of these periods are unclear, although they might be the orbital period and a superorbital period respectively. For all five sources, the long-term variability, together with the combination of orbital and proposed pulse periods, suggests that the sources contain Be star mass donors.

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108.10 – The interaction of microquasar jets with the companion wind

The interaction of relativistic jets with their environment is one of the best ways to measure their properties. This was worked extremely well in the case of AGN, where studies of X-ray cavities have have opened entirely new ways to reliably measure jet powers for entire ensembles of AGN. In the case of microquasar jets interacting with the ISM, this method is hampered by the large angular scales and low surface brightness of the observable signatures, as well as the temporary nature of the obsrvabes. However, before the jet ever reaches the ISM, it must travel through the wind from the companion star. This interaction is fundamentally different from the way AGN jets interact with their surroundings. I will discuss analytic and numerical work that investigates the unique aspects of jet-wind interaction and show how it can provide a robust and powerful diagnostic tool, complementary to other methods of constraining jet physics.

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108.11 – Black Holes and Neutron Stars in Nearby Galaxies: Insights with *NuSTAR*

There are a handful of diagnostics that permit determination of compact object identity in X-ray binaries (XRBs), and most of these are confined to bright Galactic sources for which a large number of photons can be gathered. We report on recent work using sensitive hard X-ray constraints to separate black holes from neutron stars in external galaxies with *NuSTAR*. Determining the ratio of XRBs that are black holes or neutron stars in different galactic environments reveals critical clues about the formation and evolution of binary systems. We analyze a *NuSTAR*-selected sample of ≈10 nearby galaxies within 5 Mpc that represent a range of star formation rates (0.1 - 10 $M_{\odot}\,yr^{-1}$) and stellar masses ($10^{9-11} M_{\odot}$). Using color-color and color-intensity diagnostics we classify sources by their accretion states and compact object types. We analyze the 12-25 keV X-ray luminosity functions (XLFs) of our sample scaled by specific star formation rate and compare with the 0.5-8 keV analogues. Our diagnostic methods allow us to produce black hole-only and neutron star-only extragalactic XLFs for the first time.

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108.12 – X-rays during the Cosmic Dawn

X-rays play a fundamental role in shaping the early Universe. X-rays from the first galaxies (originating from high mass X-ray binaries, the hot interstellar medium, or other sources) are expected to dominate the heating of the intergalactic medium (IGM), even before the epoch of reionization (EoR). This epoch of heating (EoH) has a dramatic imprint in the cosmic 21-cm signal. I will show how even simple metrics of the 21-cm signal during the EoH can tell us about the X-ray luminosities and SEDs of the first galaxies in our Universe. Upcoming 21-cm interferometers, HERA and SKA, will allow us to go even further, eventually providing a 3D map of the EoH. In order to take advantage of this, we created a new analysis tool for constraining the X-ray properties of the first sources in our Universe, all within a fully-Bayesian framework.

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108.13 – The Effect of Variability on X-Ray Binary Luminosity Functions

X-ray binaries are inherently variable X-ray sources, particularly at low luminosities ($<10^{36}$ erg s^{-1}). Despite this intrinsic variability, the resulting X-ray luminosity functions of X-ray binary populations in star-forming galaxies are remarkably stable across galaxies and across multiple epochs in time. We have obtained three epochs of Chandra ACIS-I observations (totaling ~184 ks) of the nearby spiral galaxy NGC 300 to study the logN-logS distributions of its X-ray point-source population down to 0.35-8 keV luminosities of $\sim10^{36}$ erg s^{-1}. The individual epoch differential logN-logS distributions are best described as the sum of a component made up of background active galactic nuclei (AGN), a simple power law, and a broken power law.

We find the shape of the logN-logS distributions sometimes varies between observations. The simple power law and AGN components produce a good fit for “persistent” sources (i.e., with fluxes that remain constant within a factor of ~2). The power-law index of ~1.2 and high fluxes suggest that the persistent sources intrinsic to NGC 300 are dominated by Roche-lobe-overflowing low-mass X-ray binaries. The variable X-ray sources are described by a broken power law, with a faint-end power-law index of ~1.7, a bright-end index of ~2.8-4.9, and a break luminosity of $\sim4 \times 10^{36}$ erg s^{-1}. This suggests that these variable sources are mostly outbursting, wind-fed high-mass X-ray binaries, although the logN-logS distribution of variable sources likely also contains low-mass X-ray binaries. We generate model logN-logS distributions for synthetic X-ray binaries and constrain the distribution of maximum X-ray fluxes attained during outburst. Our observations suggest that the majority of X-ray binaries outburst at sub-Eddington luminosities, where mass transfer likely occurs through direct wind accretion at ~1%-3% of the Eddington rate.

Author(s): Breanna A. Binder[1], Jacob Gross[5], Benjamin F. Williams[5], Michael Eracleous[3], Terrance J. Gaetz[2], Paul P. Plucinsky[2], Evan D. Skillman[4]
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108.14 – Galactic Sources Detected in the NuSTAR Serendipitous Survey

The Nuclear Spectroscopic Telescope Array (NuSTAR) provides an improvement in sensitivity at energies above 10 keV by two orders of magnitude over non-focusing satellites, making it possible to probe deeper into the Galaxy and Universe. Lansbury and collaborators recently completed a catalog of 497 sources serendipitously detected in the 3-24 keV band using 13 square degrees of NuSTAR coverage. Many of these NuSTAR "serendips" have counterparts at soft X-ray and other wavelengths, and about half of them have been classified, primarily via ground-based optical spectroscopy. While Active Galactic Nuclei (AGN) are, by far, the largest group within the classified sources, Galactic sources have also been identified based on optical spectra showing emission or absorption lines at zero redshift, previous classifications, or other observed features. We have carried out an optical and X-ray study of 16 Galactic serendips that include X-ray binaries, Cataclysmic Variables, and active stars. We focus, in particular, on constraints on the population of High-Mass X-ray Binaries (HMXBs) as their overall numbers and fraction that include black holes vs. neutron stars is relevant to predictions for the types of compact object mergers that we expect to see with gravitational wave detectors. Also, X-rays from HMXBs may be important for heating the early Universe. In addition to the HMXBs, we will report on results of observations of other serendips, including a relatively bright and variable source with unusual properties that may be an ultracompact X-ray binary. Finally, we discuss on-going work to classify more of the serendips in the Galactic plane.

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108.15 – MHD Wind Models in X-Ray Binaries and AGN

Self-similar magnetohydrodynamic (MHD) wind models that can explain both the kinematics and the ionization structure of outflows from accretion sources will be presented.
The X-ray absorption-line properties of these outflows are diverse, their velocity ranging from 0.001c to 0.1c, and their ionization ranging from neutral to fully ionized.
We will show how the velocity structure and density profile of the wind can be tightly constrained, by finding the scaling of the magnetic flux with the distance from the center that best matches observations, and with no other priors.
It will be demonstrated that the same basic MHD wind structure that successfully accounts for the X-ray absorber

properties of outflows from supermassive black holes, also reproduces the high-resolution X-ray spectrum of the accreting stellar-mass black hole GRO J1655-40 for a series of ions between ~1A and ~12A.
These results support both the magnetic nature of these winds, as well as the universal nature of magnetic outflows across all black hole sizes.

Author(s): Ehud Behar[4], Keigo Fukumura[2], Demosthenes Kazanas[3], Chris R. Shrader[3], Francesco Tombesi[5], Ioannis Contopoulos[1]
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108.16 – X-ray Pulsars in the Magellanic Clouds: Time Evolution of their Luminosities and Spin Periods

We have collected and analyzed the complete archive of XMM-Newton (116), Chandra (151), and RXTE (952) observations of the Small Magellanic Cloud (SMC), spanning 1997-2014. The resulting observational library provides a comprehensive view of the physical, temporal and statistical properties of the SMC pulsar population across the luminosity range of $L_X= 10^{31.2}-10^{38}$ erg/s. From a sample of 65 pulsars we report 1654 individual pulsar detections, yielding 1393 pulse period measurements. Our pipeline generates 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, we 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 optical counterparts to X-ray sources in the local dwarf galaxy IC 10 to form a comparison sample for Magellanic Cloud X-ray pulsars.

Author(s): Jun Yang[2], Silas Laycock[2], Malcolm J. Coe[3], Jeremy J. Drake[1], JaeSub Hong[1], Vallia Antoniou[1], Andreas Zezas[1], Wynn C. G. Ho[3]
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108.17 – On the Nature of 47 Tuc X9: Black Hole or Magnetic White Dwarf?

The LMXB X9 in the globular cluster 47 Tuc exhibits both short (28 min) and long (6.8 day) periodicities which have been interpreted by Bahramian et al (2017, MNRAS 467, 2199) as orbital and super-orbital periods respectively. Combined with an unusual X-ray to radio luminosity ratio, they propose that X9 is the first known ultra-compact black-hole X-ray binary. Here we consider an alternative interpretation where the short period is the spin period of a magnetic white dwarf in a ~2 hr orbit, i.e. that it is instead an Intermediate Polar. We suggest that the long period is due to a tilted/warped disc, a result of interactions with the donor's magnetic field, as first calculated by Murray et al (2002, MNRAS 335, 247). This naturally accounts for the large X-ray modulation, with little variation expected at other wavelengths.

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108.18 – Jets from ultraluminous X-ray sources

An important set of unsolved problems in accretion physics is whether super-Eddington accretion flows produce jets, what the jet power is (compared with the accretion power), and what the large-scale effect of the jet is on the surrounding gas. Most ultraluminous X-ray sources (ULXs) are super-Eddington stellar-mass compact objects: they provide the best local-Universe test of MHD accretion flow simulations. Observational evidence of collimated jets and fast outflows in ULXs may come in different forms: steady synchrotron radio emission from an unresolved, persistent core; radio flaring associated with discrete ejecta; internal shocks along the jet; hotspots from the jet/ISM interaction; hundred-parsec scale wind/jet-inflated nebulae. We discuss examples of the various cases, use them as proxies to measure the jet power, and compare them with (sub-Eddington) AGN and X-ray binary jets.

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108.19 – NuSTAR observations of the neutron star low-mass X-ray binary GX 349+2 throughout its Z-track

Although the brightest class of neutron star low mass X-ray binaries, known as Z-sources, have been well studied, their behavior is not fully understood. In particular, what causes these sources to trace out the characteristic Z-shaped pattern on color-color or hardness-intensity diagrams is not well known. By studying the physical properties of the different spectral states of these sources, we may better understand such variability. With that goal in mind, we present a recent *NuSTAR* observation of the Z-source GX 349+2, which spans approximately 2 days, and covers all its spectral states. By creating a hardness-intensity diagram we were able to extract four spectra and trace the change in spectral parameters throughout the Z track. GX 349+2 shows a strong, broad Fe Kα line in all states. Through modeling of the reflection spectrum and Fe Kα line we find that in most states the inner disk radius is consistent with remaining unchanged, and being close to the neutron star. However, during the brightest flaring branch the inner disk radius from reflection is not well constrained.

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108.20 – The Quiescent Neutron Star and Hierarchical Triple: 4U 2129+47

After a period of active accretion, neutron stars can enter a phase where their X-ray emission is dominated by thermal emission from their surface. The rate of cooling of this emission can yield insight into neutron star structure. Furthermore, emission models may help determine the neutron star radius. A number of questions arise when modeling such X-ray spectra as observed by Chandra or XMM-Newton. Is there ongoing, low level active accretion that is contributing to the observed soft X-ray emission? In a number of cases, a hard X-ray tail is also observed. What is the origin of this hard tail? The quiescent neutron star system 4U 2129+47 presents a unique opportunity to study these questions. This system is viewed nearly edge on, as evidenced by a periodic, total eclipse that lasts 1585 seconds out of the 5.24 hour orbit. As we are viewing this system edge on, both observed neutral column variations and an observed hard X-ray tail in year 2000 Chandra observations indicated ongoing active accretion. Subsequent XMM and Chandra observations over the next 15 years showed that both the neutral column variability and the hard X-ray tail vanished. Thus, these later observations may represent a true quiescent, cooling neutron star state. We assess the evidence for cooling in the 4U 2129+47 system. Furthermore, we use the timing of the X-ray eclipses to discuss evidence for a third body in the system, and derive likely orbital periods. Finally, we discuss how future X-ray missions, e.g., Athena and Lynx, could place more stringent limits on neutron star cooling and the presence of a hard tail (i.e., active accretion) in this system.

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108.21 – Magnetized Black Hole Accretion Disks with Poloidal Flux

Observations of blueshifted absorption lines associated with black hole X-ray binary accretion disk winds sometimes imply a magnetic driving mechansim. To study the properties of magnetized disks, we performed shearing box simulations (stratified, isothermal, ideal MHD) with different amounts of net vertical magnetic flux, spanning essentially the entire range over which the MRI is linearly unstable. This net vertical flux sets the strength of the dominant toroidal field that is generated by the MRI-dynamo. Given sufficiently large net vertical flux, magnetic pressure support against gravity dominates throughout the vertical column of the disk. Without net poloidal flux, a strongly magnetized state cannot persist because the toroidal field buoyantly escapes faster than it can be replenished. With increasing disk magnetization: (1) toroidal field reversals characteristic of the MRI-dynamo become less frequent and more sporadic and (2) gas density becomes more inhomogeneous, with field concentrating in low-density regions. We are currently investigating whether magnetic pressure support in the disk atmosphere alters the disk continuum spectrum, which would bring the robustness of black hole spin measurements into question.

Author(s): Greg Salvesen[2], Jacob B. Simon[1], Philip J. Armitage[3], Mitchell C. Begelman[3]
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108.22 – X-ray Pulsars Across the Parameter Space of Luminosity, Accretion Mode, and Spin

We present our multi-satellite library of X-ray Pulsar observations to the community, and highlight recent science results. Available at www.xraypulsars.space the library provides a range of high-level data products, including: activity histories, pulse-profiles, phased event files, and a unique pulse-profile modeling interface. The initial release (v1.0) contains some 15 years of RXTE-PCA, Chandra ACIS-I, and XMM-PN observations of the Small Magellanic Cloud, creating a valuable record of pulsar behavior. Our library is intended to enable new progress on fundamental NS parameters and accretion physics. The major motivations are (1) Assemble a large homogeneous sample to enable population statistics. This has so far been used to map the propeller transition, and explore the role of retrograde and pro-grade accretion disks. (2) Obtain pulse-profiles for the same pulsars on many different occasions, at different luminosities and states in order to break model degeneracies. This effort has led to preliminary measurements of the offsets between magnetic and spin axes. With the addition of other satellites, and Galactic pulsars, the library will cover the entire available range of luminosity, variability timescales and accretion regimes.

Author(s): Silas Laycock[5], Jun Yang[5], Dimitris Christodoulou[5], Malcolm Coe[3], Rigel Cappallo[5], Andreas Zezas[2], Wynn C. G. Ho[3], JaeSub Hong[2], Samuel Fingerman[4], Jeremy J. Drake[2], Peter Kretschmar[1], Vallia Antoniou[2]

Institution(s): *1. European Space Astronomy Centre, 2. Harvard Smithsonian Center for Astrophysics , 3. Southampton University, 4. UMass Lowell Center for Space Science and Technology, 5. University of Massachusetts Lowell*

108.23 – An X-Ray Study of NGC 7331

We report on Chandra X-ray Observatory ACIS-S observations of the spiral galaxy NGC 7331. There are 50 X-ray point sources, including SN 2014C, identified by combining five observations taken between 2001 and 2015 within the optical D_{25} region of NGC 7331 with a signal to noise ratio (S/N) larger than 3. The detection limit of our sample is 1.3×10^{38}ergs s^{-1} in the 0.5-7.0 keV energy band. Fifteen of them are variable with variability larger than 3σ. The cumulative luminosity function of point sources can be fitted with a broken power-law with a luminosity break at 3.6×10^{38} ergs s-1 while the slope is 0.6 and 2.04 before and after the break, respectively. This may indicate a mixture of bright and young sources on the spiral arms, and older disk populations as studied in other late type galaxies. For the five sources with net counts larger than 120, the spectral model fittings are carried out with absorbed power-law, Raymond-Smith and blackbody models. The spectral fitting of SN 2014C shows a decrease of column density with time and the photon indices vary from -0.24 to 0.87. As for the other four sources, the average power-law photon index is about 1.6. By adopting the classification method proposed by Prestwich et al. (2003) according to the X-ray color-color diagram of the sources with S/N larger than 4, we find 9 sources that are likely to be low-mass X-ray binaries. We plan to use the observations taken with the Hubble Space Telescope (HST) Wide Field and Planetary Camera 2 (WFPC2) and Wide Field Camera 3 (WFC3) to identify optical counterparts lying in the error ellipses of X-ray sources in the future.

Author(s): Ruolan Jin[1], Albert K. H. Kong[1]
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108.24 – Timing analysis of a unique hard X-ray source, Swift J0042.6+4112, in M31

Recent NuSTAR-Swift observations revealed that a single resolved X-ray source, Swift J0042.6+4112, with Lx of a few times 10^{38} erg/s dominates the hard X-ray emission from the Andromeda galaxy. HST-based stellar population synthesis modeling combined with the 0.5-50 keV spectral shape suggest that this might be an X-ray pulsar with an intermediate (or lower) mass donor. Here we further explore the alternative scenario of a symbiotic or ultracompact X-ray binary, based on long-term variability from Swift observations between 2005 and 2016. We find that the soft (0.3-8.0 keV) X-ray flux varies within a factor of 4 but does not exhibit transient behavior. Its power spectrum suggests a 6.1-day period, which, if interpreted as an orbital period, would not support either the symbiotic or the ultracompact X-ray binary scenario. Finally, we also present the hard X-ray variability of this source deduced from a new NuSTAR observation in 2017.

Author(s): Mihoko Yukita[2], Panayiotis Tzanavaris[4], Robin Corbet[4], Andrew Ptak[4], Ann E. Hornschemeier[4], Katja Pottschmidt[4], Ralf Ballhausen[1], Teruaki Enoto[3], Vallia Antoniou[5], Bret Lehmer[8], Thomas J. Maccarone[6], Daniel R. Wik[2], Benjamin F. Williams[7], Andreas Zezas[5]
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108.25 – A New Accreting Millisecond X-ray Pulsar: IGR J17062-6143

We present the discovery that the bursting, neutron star binary IGR J17062-6143 is a 164 Hz accreting millisecond X-ray pulsar (AMXP). We detected the pulsations in the only observation obtained of the source with the Rossi X-ray TIming Explorer (RXTE). We find evidence for variations in the pulsation frequency consistent with binary motion of the neutron star. The observation length (~1200 s) was too short to measure the orbital period, but coherent phase timing excludes periods shorter than about 17 minutes. The mean source pulsed amplitude is 9.4 +- 1.1 % (half amplitude). For the range of acceptable circular orbits we find that the inferred binary mass function substantially overlaps the observed range for the AMXP populatoin as a whole. IGR J17062-6143 is the slowest spinning AMXP presently known.

Author(s): Tod E. Strohmayer[2], Laurens Keek[1]
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108.26 – Simple Formula Relating Frequencies of Twin-peak Quasiperiodic Oscillations

Twin-peak quasiperiodic oscillations are observed in several low-mass X-ray binary systems containing neutron stars. Timing analysis of X-ray fluxes of more than dozen of such systems reveals remarkable correlations between frequencies of two characteristic peaks present in the power density spectra. Several attempts to model these correlations with simple geodesic orbital models or phenomenological relations have failed in the past. We find and explore a surprisingly simple analytic formula that well reproduces individual correlations for a large group of sources. We also discuss possible theoretical interpretation of this formula.

Author(s): Gabriel Torok[1]
Institution(s): *1. Silesian University in Opava*

108.27 – Some properties of orbital motion in the Hartle-Thorne metric

The external Hartle-Thorne metric properly describes the external gravitational field of rotating compact objects in general relativity. This spacetime is characterized by gravitational mass M, angular momentum J and quadrupole moment Q. We investigate properties of orbital motion around rotating neutron stars with combinations of M, J, Q based on modeling of the rotating stars using realistic equations of state of neutron star matter.
We particularly focus on impact of angular momentum and quadrupole moment of the star on epicyclic motion of matter around rotating neutron stars. This serves as a toy model for accretion disks and their oscillation frequencies. Our research is motivated by the X-ray observations of low-mass X-ray binaries where neutron star accretes matter from its binary companion and radiates in X-rays.

Author(s): Gabriela Urbancova[1]
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108.28 – Innermost Stable Circular Orbits Around Rotating Compact Stars

Orbital motion close to a rotating neutron star (NS) is affected by effects of strong gravity. Keplerian frequency at the innermost stable circular orbit (ISCO frequency) depends on the interplay between relativistic effects and geometric Newtonian effects given by NS oblateness, and may increase as well as decrease when NS angular momentum increases. In this context we examine a large set of NS equations of state (EoS) as well as strange star (QS) EoS. We find simple approximative formulae determining the ISCO frequency for a given gravitational mass M and rotational frequency of the compact star (NS or QS).

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108.29 – Discoveries of high-frequency QPOs from intermediate-mass black holes with XMM, RXTE and NICER

Stable, twin-peak X-ray quasi-periodic oscillations (QPOs; frequency range of 100-450 Hz) in a 3:2 frequency ratio have been observed from a sample of stellar-mass black holes (e.g., Belloni et al. 2012). These frequencies scale inversely with the black hole mass as expected from general relativistic motion near a black hole. Under the black hole unification paradigm, it has been argued that intermediate-mass black holes (IMBH) should also exhibit the 3:2 ratio high-frequency QPOs, but at frequencies lower than stellar-mass black holes. Thence, such QPOs will provide an accurate measurement of IMBH masses (Abramowicz et al. 2004).

Combining all the entire archival RXTE/PCA observations of the ultraluminous X-ray source (ULX) M82 X-1, we discovered stable, twin-peak X-ray QPOs at 3.3 and 5 Hz (3:2 frequency ratio). Scaling these frequencies to the oscillations of the stellar-mass black holes of known mass implies that M82 X-1's black hole is 428+-105 solar masses (Pasham, Strohmayer & Mushotzky 2014). We discovered similar 3:2 frequency ratio QPOs from another ULX NGC 1313 X-1 (0.30 and 0.45 Hz). These frequencies imply a black hole mass of 5000+-1300 solar masses in NGC 1313 X-1 (Pasham et al. 2015b). In addition to these results I will discuss some early results from NICER observations of ULXs.

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108.30 – Chandra/HETGS observations of SMC X-3 in the Super Eddington phase.

Recent work has revealed three ultra luminous X-rays sources (ULXs) to be powered by accretion onto a high B-field neutron star. These results suggest that neutron stars contribute to a large fraction of the observed ULX population and has re-invigorated interest in the super Eddington accretion phenomenon. The population of local high magnetic field neutron stars present an opportunity to study such high luminosity accretion flows. The Be/X-ray binary systems are excellent targets, with large magnetic fields (> 1e12 G) and quasi-regular outbursts that reach values far in excess of the Eddington limit for a canonical neutron star (Lx > 2e38 erg/s). We will present the results of a high spectral resolution Chandra/HETGS observation of the Small Magellanic Cloud Be/X-ray binary SMC X-3 during a giant/type-II outburst in 2016. The source was observed at a luminosity of Lx ~ 2e39 erg/s or approximately 10 times the Eddington limit. The high quality grating data reveal numerous highly ionized emission lines. We will discuss the constraints the observed lines place on our understanding of models for super Eddington accretion inflow/outflow onto a highly magnetized neutron star.

Author(s): Mark Reynolds[3], Malcolm Coe[4], Jon M. Miller[3], Jamie A Kennea[1], Phil Evans[2]
Institution(s): *1. Pennsylvania State University, 2. University of Leicester, 3. University of Michigan, 4. University of Southampton*

108.31 – Phase-resolved spectroscopy of the low-mass X-ray binary system 4U 1636-536/V801 Ara

4U1636-543/V801 Ara observations covering the full binary orbit of 3.8 days were obtained with the IMACS instrument on the 6.5m Walter Baade Telescope at Las Campanas. Our tomograms of the system in H-alpha and H-beta clearly detect the accretion disk but the disk is not centered on the center-of-mass of the neutron star. This offset has been seen also in the persistent NS LMXB, X1822-371 and implies disk precession. Instead of a hot spot as is expected at the point where the accretion stream hits the disk these tomograms show enhanced emission below this region. Lack of a hot spot and emission at a further point on the disk implies a gas stream interaction downstream of the hot spot as also seen in X1822-371 and other similar systems (eg EXO0748-676). The radial velocity curve of H-alpha does not show strong orbital modulation which is consistent with emission dominated by the disk. The radial velocity curves of the Bowen blend show strong modulation at the orbital period as expected for emission originating on the secondary and the tomogram suggests emission from the heated side of the secondary.

Author(s): Saeqa Dil Vrtilek[3], Kaley Brauer[1], Charith Peris[3], Bram Boroson[2], Michael McCollough[3]
Institution(s): *1. Brown University, 2. Clayton State University, 3. Harvard-Smithsonian, CfA*

108.32 – Classification of X-ray point sources in external galaxies

The exquisite spatial resolution of the Chandra X-ray satellite allows us to resolve individual X-ray point sources in external galaxies. We have extracted data on extragalactic X-ray binary candidates from 150 external galaxies including a selection of elliptical, spiral, and starburst galaxies with a range of metallicities. By using X-ray binaries containing neutron stars or black holes from our own Galaxy that were multiply observed by Chandra as a training set we classify the accretion type of each object individually identified in the external galaxies. We find systematic differences in the binary populations of different classes of galaxy. Our study provides information on populations of X-ray sources in different galaxy types which has implications for the evolution of galaxies, as well as clues about how the different classes of XRBs are related to each other.

Author(s): Saeqa Dil Vrtilek[1], Nazma Islam[2], Dong-Woo Kim[1], Michael McCollough[1]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. Nicolas Copernicus Astronomical Center*

108.34 – A Complete Binary Orbit of Cygnus X-1: Spectroscopic Analysis

In 2016 we observed the canonical black hole binary system Cyg X-1/HDE226868 for a full 5.6-day orbit. We present preliminary results of the ionization state and composition of the plasma surrounding the black hole by looking at the XMM-Newton RGS spectra. Using newly improved reflection models, which include a Comptonization continuum, density and radial ionization effects; we also present an analysis of the reflected spectra observed simultaneously with XMM-Newton and NuSTAR, effectively covering the 0.3-50 keV energy range.

Author(s): Javier Garcia[1], Phil Uttley[4], Joern Wilms[2], Victoria Grinberg[3], Katja Pottschmidt[5], Thomas Dauser[2]
Institution(s): *1. Caltech, 2. Dr. Karl-Remeis Observatory, 3. ESTEC, 4. University of Amsterdam, 5. University of Maryland*

108.35 – Phase-resolved spectra of burst oscillations in Neutron Stars

Millisecond oscillations have been observed during thermonuclear bursts from many neutron stars (NS) in LMXBs. Their periods are comparable to the rotational period of the NS, and are thought to be produced by temperature anisotropies on the NS surface. Understanding and correcly modeling these oscillation is a powerful tool to constrain the NS interior. Studying these oscillations has thus far focused on modeling the oscillation profile form these pulsations using mostly XTE data. Here, we take a different approach and extract spectra at different phases of the oscillations. This allows us track the observed spectrum as the NS rotates. We are able to measure temperature changes as the star rotates. The temperature profiles from some bursts show asymetries likely due to Doppler effects. Here, we present detailed results from the phase spectra and discuss their implications on measurements of NS masses and radii.

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108.36 – A flux state comparison of the transient X-ray pulsar SAX J2103.5+4545

We present the first NuSTAR observations of SAX J2103.5+4545, a Be X-ray binary with a history of X-ray flares occurring every 2-3 years. We carried out two Target of Opportunity observations in spring of 2016, as J2103 went into outburst with the strongest flux seen from this object since the launch of NuSTAR. We obtained high-quality X-ray spectra in both epochs, with one observation capturing the bright precursor flare for the first time. We fit the spectra with an NPEX (Negative and Positive power law with an EXponential cut-off) model with Gaussian emission lines to constrain the iron line complex and detect a highly ionized iron line at 6.9 keV for the first time. We perform pulse-phase spectroscopy and find that the model parameters do not vary significantly with pulse phase, which has implications for the geometry and orientation of the accretion flow. We also detect a weak absorption feature at ~12 keV that shows strong pulse phase dependence and could, with further study, be classified as a cyclotron resonance scattering feature. If this line is related to cyclotron scattering, it would imply that J2103 has an unusually low magnetic field (~1e12 G) and opens the possibility of using NuSTAR to detect similar features in other transient X-ray pulsars.

Author(s): McKinley Brumback[1], Ryan C. Hickox[1], Felix Fuerst[3], Katja Pottschmidt[6], Paul Britton Hemphill[4], John Tomsick[5], Joern Wilms[2]
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108.37 – Rapid Jet Precession During the 2015 Outburst of the Black Hole X-ray Binary V404 Cygni

In stellar-mass black holes that are orbited by lower-mass companions (black hole low-mass X-ray binaries), the accretion process can undergo dramatic outbursts that can be accompanied by the launching of powerful relativistic jets. We still do not know the exact mechanism responsible for launching these jets, despite decades of research and the importance of determining this mechanism given the clear analogue of accreting super-massive black holes and their jets. The two main models for launching jets involve the extraction of the rotational energy of a spinning black hole (Blandford–Znajek) and the centrifugal acceleration of particles by open magnetic field lines rotating with the accretion flow (Blandford-Payne). Since some relativistic jets are not fully aligned with the angular momentum of the binary's orbit, the inner accretion flow of some black hole X-ray binaries may precess due to frame-dragging by a spinning black hole (Lense-Thirring precession). This precession has been previously observed close to the black hole as second-timescale quasi-periodic (X-ray) variability. In this talk we will present radio-through-sub-mm timing and high-angular resolution radio imaging (including a high-timing resolution movie) of the black hole X-ray binary V404 Cygni during its 2015 outburst. These data show that at the peak of the outburst the relativistic jets in this system were precessing on timescales of hours. We will discuss how rapid precession can be explained by Lense-Thirring precession of a vertically-extended slim disc that is maintained out to a radius of 6×10^{10} cm by a highly super-Eddington accretion rate. This would imply that the jet axis of V404 Cyg is not aligned with the black hole spin. More importantly, this places a key requirement on any model for launching jets, and may favour launching the jet from the rotating magnetic fields threading the disc.

Author(s): Gregory R. Sivakoff[2], James Miller-Jones[1], Alex J. Tetarenko[2]
Institution(s): *1. International Centre for Radio Astronomy Research – Curtin University, 2. Univ. of Alberta*

108.38 – The field LMXB populations of local early-type galaxies

We present the results of our ongoing study of the low mass X-ray binary (LMXB) populations of local early-type galaxies. By combining deep Chandra observations with HST optical mosaics, we have determined the field LMXB populations of nine local early-type galaxies. We use these data to determine the specific frequency of LMXBs in these galaxies, n_x (the number of LMXBs per stellar K-band light). We find that the shape of the XLF is similar among these galaxies, but also find a significant variation in the scaling. We test for correlations between n_x and galaxy: velocity dispersion; metallicity and Mg abundance; globular cluster specific frequency; and proposed IMF variation. No significant correlations are observed and we note the need to expand the sample of galaxies further to understand the underlying reason for variations in the formation efficiency of LMXBs in these galaxies.

Author(s): Mark Peacock[2], Steve E. Zepf[2], Arunav Kundu[1], Thomas J. Maccarone[3], Bret Lehmer[5], Claudia Maraston[7], Anthony H. Gonzalez[6], Rafael T. Eufrasio[5], Daniel Coulter[4]
Institution(s): *1. Eureka Scientific, 2. Michigan State University, 3. Texas Tech University, 4. UC Santa Cruz, 5. University of Arkansas, 6. University of Florida, 7. University of Portsmouth*

108.39 – NuSTAR Observation of the Symbiotic System GX 1+4

We report on a NuSTAR observation of the symbiotic binary system GX 1+4. GX 1+4 is one of a small number of systems with a red giant mass donor and a magnetic neutron star in orbit around each other. The accreting pulsar in GX 1+4 has a spin period of ~150 seconds with epochs of both spin-up and spin-down. The orbital period that has not been determined. Magnetic accretion theory in such systems suggests that the neutron star has a magnetic field in the range 10^{13}-10^{14} Gauss although this is not settled because no cyclotron absorption feature has been observed in the X-ray spectrum. The NuSTAR spectrum shows broad Fe-line emission near ~6.5 keV and also shows a broad power law shape detected up to ~60 keV. We analyze and discuss the NuSTAR X-ray data with particular attention to the question of what can the spectrum tell us about the structure of the accretion flow onto the neutron star and the magnetic field strength.

Author(s): Michael Thomas Wolff[3], Peter A. Becker[1], Teruaki Enoto[2], Katja Pottschmidt[5], Kent Wood[4]
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108.40 – Monitoring the 2010-2015 Hard X-ray/Low-Energy Gamma-Ray Activity of Cygnus X-1 with GBM

Cygnus X-1 is a high-mass X-ray binary with a black hole companion that typically resides in a hard spectral state, where it is extremely bright in hard X-rays and low energy gamma rays and much fainter in the soft X-rays. Since 2008 August, we have used the Gamma-Ray Burst Monitor (GBM) on Fermi to monitor Cyg X-1 in the 10-1000 keV energy range using the Earth occultation technique. Starting in the middle of 2010, Cyg X-1 was observed by GBM to enter a period of increased activity, making several transitions to the soft state, characterized by the typical rise in the soft X-ray flux and decrease in the hard x-ray and low energy gamma-ray flux. From the soft state, Cyg X-1 made several transitions to intermediate states as well as several short transitions back to the hard state. At the end of 2015, Cyg X-1 transitioned back to the canonical hard state, where it has remained ever since. We have generated long-term, broad-band light curves based on daily monitoring of Cyg X-1 over a 9 year period showing the hard-to-soft state transitions, the intermediate states, and the soft-to-hard and failed soft-to-hard state transitions. Spectra are presented of Cyg X-1 in the various states and comparisons made between spectra in the same state. The time evolution of the x-ray hardness ratios is also presented.

Author(s): Gary L. Case[1], Peter Jenke[2], Colleen A. Wilson-Hodge[3]
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108.41 – Spectral-Timing Analysis of Kilohetrz Quasi-Periodic Osciallations in Neutron Star Low-Mass X-ray Binaries

Kilohertz quasi-periodic oscillations or kHz QPOs are intensity variations that occur in the X-ray band observed in neutron star low-mass X-ray binary (LMXB) systems. In such systems, matter is transferred from a secondary low-mass star to a neutron star via the process of accretion. kHz QPOs occur on the timescale of the inner accretion flow and may carry signatures of the physics of strong gravity ($c^2 \sim GM/R$) and possibly clues to constraining the neutron star equation of state (EOS). Both the timing behavior of kHz QPOs and the time-averaged spectra of these systems have been studied extensively. No model derived from these techniques has been able to illuminate the origin of kHz QPOs. Spectral-timing is an analysis technique that can be used to derive information about the nature of physical processes occurring within the accretion flow on the timescale of the kHz QPO. To date, kHz QPOs of (4) neutron star LMXB systems have been studied with spectral-timing techniques. We present a comprehensive study of spectral-timing products of kHz QPOs from systems where data is available in the *RXTE* archive to demonstrate the promise of this technique to gain insights regarding the origin of kHz QPOs. Specifically, we show correlated time-lags as a function of QPO frequency and energy for the various LMXB systems where kHz QPOs are detected.

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108.42 – Simulating a Thin Accretion Disk Using *PLUTO*

Accreting black hole systems such as X-ray binaries and active galactic nuclei exhibit variability in their luminosity on many timescales ranging from milliseconds to tens of days, and even hundreds of days. The mechanism(s) driving this variability and the relationship between short- and long-term variability is poorly understood. Current studies on accretion disks seek to determine how the changes in black hole mass, the rate at which mass accretes onto the central black hole, and the external environment affect the variability on scales ranging from stellar-mass black holes to supermassive black holes. Traditionally, the fluid mechanics equations governing accretion disks have been simplified by considering only the kinematics of the disk, and perhaps magnetic fields, in order for their phenomenological behavior to be predicted analytically. We seek to employ numerical techniques to study accretion disks including more complicated physics traditionally ignored in order to more accurately understand their behavior over time. We present a proof-of-concept three dimensional, global simulation using the astrophysical hydrodynamic code PLUTO of a simplified thin disk model about a central black hole which will serve as the basis for development of more complicated models including external effects such as radiation and magnetic fields. We also develop a tool to generate a synthetic light curve that displays the variability in luminosity of the simulation over time. The preliminary simulation and accompanying synthetic light curve demonstrate that PLUTO is a reliable code to perform sophisticated simulations of accretion disk systems which can then be compared to observational results.

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108.43 – Probing the Circumstellar Environment of the Supergiant Fast X-ray Transient IGR J17544-2619 with K2 and Swift

We report on a multi-wavelength study of IGR J17544-2619, the prototypical Supergiant Fast X-ray Transient (SFXT) with the most extreme dynamic range and one of the shortest orbital periods. Consisting of a neutron star in a 4.9 day orbit around a mass donor with spectral type O9 Ib, IGR J17544-2619 has previously shown large scale X-ray variability up to 6 orders of magnitude on timescales of hours as well as long quiescent periods on the order of tens of days. To study its optical, ultraviolet and X-ray properties on orbital and sub-orbital timescales, we monitored IGR J17544-2619 with continuous 80 day Campaign 11 K2 data (MJD 57655-57730) along with simultaneous Swift Target of Opportunity observations. Using the Swift X-ray Telescope, we find a maximum X-ray flux of (1.0+/-0.3)X10^-10 erg cm^-2 s^-1 in the 0.3-10 keV band. No luminous X-ray outbursts were found. We compare Swift ultraviolet and

X-ray observations with uninterrupted one minute short cadence K2 optical data using the zero crossing and the discrete cross-correlation function methods.

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108.44 – Spectral and Temporal Morphology of the Superorbital Modulation in the X-ray Binary IGR J16493-4348

Periodic variability in the highly obscurred Supergiant X-ray Binary (SGXB) IGR J16493-4348 is seen on three different timescales: a ~1092 s neutron star rotation period, a ~6.8 day orbital period and a ~20.07 day superorbital period. We present NuSTAR and Swift X-ray Telescope (XRT) observations of IGR J16493-4348 near the minimum and maximum of its ~20.07 day superorbital period. Using epoch folding, we refine the rotation period of the neutron star to 1091.7+/-0.8 s. The pulse profile is found to show some energy dependence, evolving from double peaked below 20 keV and single peaked above this. We find the pulse fraction to be 0.32+/-0.04, 0.35+/-0.03, 0.46+/-0.05, 0.66+/-0.07 and 0.81+/-0.11 in the 3-6 keV, 6-10 keV, 10-20 keV, 20-30 keV and 30-50 keV bandpasses. This shows a near monotonic increase with energy. The best-fit spectral model at superorbital maximum consists of a power law with spectral index 1.37+/-0.05 and a high energy cutoff at 7.9+/-0.3 keV modified by an absorber that fully covers the source. No cyclotron resonant scattering features (CRSF) are found in the broadband spectra, even though a possible CRSF was previously reported at 33 keV. A preliminary pulse phase resolved spectroscopy reveals a hint of spectral changes in the folding energy and spectral index over the rotation period of the neutron star.

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108.45 – Twin-Peak QPOs from Oscillating Torus with Cusp

We propose a model of HF twin-peak quasi-periodic oscillations assuming an oscillating torus with cusp that changes location of its centre around radii very close to innermost stable circular orbit. The observed variability is assigned to global modes of accreted fluid motion that may give rise to strong modulation of both the accretion disc radiation and the accretion rate. We illustrate that predictions of the model well match observational data for a dozen of sources.

Author(s): Eva Sramkova[1]
Institution(s): *1. Silesian University in Opava*

108.46 – Missing upper kHz QPO in MHD simulations of oscillating cusp-filling tori

We performed axisymmetric, grid-based, ideal magnetohydrodynamic (MHD) simulations of oscillating cusp-filling tori orbiting a non-rotating neutron star. A pseudo-Newtonian potential was used to construct the constant angular momentum tori in equilibrium. The inner edge of the torus is terminated by a "cusp" in the effective potential. The initial motion of the model tori was perturbed with uniform sub-sonic vertical and diagonal velocity fields. As the configuration evolved in time, we measured the mass accretion rate on the neutron star surface and obtained the power spectrum. The prominent mode of oscillation in the cusp torus is the radial epicyclic mode. It would appear that vertical oscillations are suppressed by the presence of the cusp. From our analysis it follows that the mass accretion rate carries a modulation imprint of the oscillating torus, and hence so does the boundary layer luminosity.

Author(s): Wlodek Kluzniak[1], Varadarajan Parthasarathy[1], Miljenko Čemeljić[1]
Institution(s): *1. Copernicus Astronomical Center*

109 – Black Holes, Neutron Stars and ULX Sources Poster Session

109.02 – Disk--Jet Coupling Following a Stellar Tidal Disruption Flare

Tidal disruption of stars by supermassive black holes can result in transient radio emission. The electrons producing these synchrotron radio flares could be accelerated inside a relativistic jet or externally by shocks resulting from the interaction of an outflow with the circumnuclear medium. Until now, evidence for internal emission has been lacking and nearly all tidal disruption flare studies have adopted the external shock model to explain the observed properties of radio flares. I will talk about our recent discovery of a correlation between the changes in the x-ray and the radio flux of a tidal disruption flare. The radio lags the x-ray emission by about 13 days. This demonstrates that the x-ray emitting accretion disk regulates the radio emission. This coupling is inconsistent with all previous external models but is naturally explained if the radio emission originates from a freely expanding jet. I will also discuss the importance of similar observations in the future to understand how jets evolve in their earliest stages.

Author(s): Deeraj Ranga Reddy Pasham[2], Sjoert van Velzen[1]
Institution(s): *1. Johns Hopkins University, 2. MIT*

109.03 – Adolescent Black Holes May be Hard to Find

Finding adolescent black holes that are growing rapidly from their seed masses is a major goal of the next generation of large observatories. We have examined how these early quasars may appear in terms of their broad emission lines (BELs) in the optical and ultraviolet. We find that below 10**6 Msol, the equivalent widths of the BELs drop precipitously. Moreover, if the BELs originate in clouds that form as the cool phase of a multi-phase medium, then for metallicities Z/Zsol ~< 3, the thermal instabilities that create them will not exist. However, in observed quasars at high redshift Z/Zsol is >> 3, so quasars are preferentially found in special environments, perhaps with deep potential wells. The population that we see though could be biased by the Z/Zsol > 3 requirement. A stronger argument is that the thermal instability leading to cool clouds is predominantly due to line emission by iron. Iron comes primarily from type 1a supernovae, which take of order 1 billion years to ignite. Hence iron should be under-abundant relative to other elements until z ~ 6 - 7. That the highest redshift quasar is at z = 7.1 may be a consequence of this requirement. Quasars above z ~ 7 could still be found by their rest-frame ultraviolet or X-ray continuum.

Author(s): Martin Elvis[1], Susmita Chakravorty[2]
Institution(s): *1. Harvard-Smithsonian CfA, 2. Indian Institute of Astronomy*

109.04 – Simultaneous Monitoring of X-ray and Radio Variability in Sagittarius A*

We report on joint X-ray/radio campaigns targeting Sagittarius A*, including 9 contemporaneous Chandra and VLA observations. These campaigns are the most extensive of their kind and have allowed us to test whether the black hole’s variations in different parts of the electromagnetic spectrum are due to the same physical processes. We detect significant radio variability peaking >176 minutes after the brightest X-ray flare ever detected from Sgr A*. We also identify other potentially associated X-ray and radio variability, with radio peaks appearing <80 minutes after weaker X-ray flares. These results suggest that stronger X-ray flares lead to longer time lags in the radio. However, we also test the possibility that the variability at X-ray and at radio wavelengths are not temporally correlated, and show that the radio variations occurring around the time of X-ray flaring are not significantly greater than the overall radio flux variations. We also cross-correlate data from mismatched X-ray and radio epochs and obtain comparable correlations to the matched data. Hence, we find no overall statistical evidence that X-ray flares and radio variability are correlated, underscoring a need for more simultaneous, long duration X-ray-radio monitoring of Sgr A*.

Author(s): Daryl Haggard[4], Daniel M. Capellupo[4], Nicolas Choux[4], Frederick K. Baganoff[5], Geoffrey C. Bower[1], William D. Cotton[7], Nathalie Degenaar[11], Jason Dexter[3], Heino Falcke[8], P. Christopher Christopher Fragile[2], Craig O. Heinke[10], Casey J. Law[9], Sera Markoff[11], Joseph Neilsen[5], Gabriele Ponti[3], Nanda Rea[11], Farhad Yusef-Zadeh[6]
Institution(s): *1. ASIAA, 2. College of Charleston, 3. Max Planck Institute for Extraterrestrial Physics, 4. McGill University/McGill Space Institute, 5. MIT Kavli Institute, 6. Northwestern University/CIERA, 7. NRAO, 8. Radboud University, 9. UC Berkeley/LBNL, 10. University of Alberta, 11. University of Amsterdam*

109.05 – Super-Eddington Accreting Tidal Disruption Events

Multiwavelength flares from tidal disruption and subsequent accretion of stars are important for study of otherwise dormant massive black holes in galactic nuclei. Previous well-monitored candidate flares were short-lived, with most emission confined to within ~1 year. Here, we report our discovery of a well observed super-long (>11 years) luminous X-ray flare from the nuclear region of a dwarf starburst galaxy. After an apparently fast rise within ~4 months a decade ago, the X-ray luminosity, though showing a weak trend of decay, has been persistently high at around the Eddington limit. The X-ray spectra are soft and can be described with Comptonized emission from an optically thick low-temperature corona, a super-Eddington accretion signature often observed in accreting stellar-mass black holes. Dramatic spectral softening was also caught in one recent observation, implying either a temporary transition from the super-Eddington accretion state to the standard thermal state, or the presence of a transient highly blueshifted (~0.36c) warm absorber. All these properties in concert suggest a tidal disruption event with an unusually long super-Eddington accretion phase that has never before been observed. We also found two additional events showing similar X-ray spectra characteristic of super-Eddington accretion from two otherwise quiescent galaxies. Therefore these events seem to form a new, super-Eddington accreting class of tidal disruption events.

Author(s): Dacheng Lin[11], James Guillochon[4], St. Komossa[8], Enrico Ramirez-Ruiz[10], Jimmy Irwin[9], W. Peter Maksym[4], Dirk Grupe[6], Olivier Godet[5], Natalie Webb[5], Didier Barret[5], Bevin Zauderer[7], Pierre-Alain Duc[2], Eleazar R. Carrasco[3], Stephen Gwyn[1]
Institution(s): *1. Canadian Astronomy Data Centre, 2. CEA-Saclay, 3. Gemini Observatory, 4. Harvard-Smithsonian Center for Astrophysics, 5. IRAP, 6. Morehead State University, 7. New York University, 8. QianNan Normal University for Nationalities, 9. University of Alabama, 10. University of California, Santa Cruz, 11. University of New Hamsphire*

109.06 – X-ray flaring from Sagittarius A*: exploring the Milky Way black hole through its brightest flares

Sagittarius A* is the supermassive black hole at the center of our own Milky Way galaxy. Ambitious monitoring campaigns have yielded rich multiwavelength, time-resolved data, which have the power to probe the physical processes that underlie Sgr A*'s quiescent and flare emission. In 2013 and 2014 the Chandra X-ray Observatory captured two extremely luminous flares from Sgr A*, the two brightest ever detected in X-ray. I will describe the spectral and temporal properties of these flares, how they compare to previous analysis, and the possible physical processes driving the Sgr A* variability. I will also discuss the power spectral densities of the flares which may contain information about the black hole's ISCO and spin.

Author(s): Melania Nynka[1], Daryl Haggard[1]
Institution(s): *1. McGill University*

109.07 – *NuSTAR* monitoring of the Galactic center diffuse emission

Over the past two decades, the intense X-ray monitoring of the Molecular clouds in the inner region of our Galaxy has revealed a large number of reflection features, characterized by both a strong iron line at 6.4keV and associated non-thermal continuum emission. The correlated variations of these structures observed within the whole central molecular zone, along with their surface brightness, are strong evidence that a significant fraction of this diffuse emission is created by past outbursts from the supermassive black hole at the Galactic center, Sagittarius A*. The variability and the intensity of the fluorescent iron line derived from *XMM-Newton* and *Chandra* campaigns have demonstrated that the past events were short (few-year duration) but intense (more than 10^{39} erg/s in luminosity). However, reconstructing the detailed properties of these past events is not straightforward since it also depends on the density and the line of sight distances of the reflecting clouds, which are poorly known. By better constraining the diffuse continuum emission up to several tens of keV, *NuSTAR* now provides spectral information needed to better understand both the spectral shape of the emission produced during these past events and the geometry of the reflecting clouds. I will present the up-to-date *NuSTAR* results on the past activity of Sgr A*, including a detailed comparison of the latest 2016 deep observation with the original 2012 survey of the Galactic center and a complete spectral analysis of the Arches cloud and of an other key cloud which has been brightening.

Author(s): Maïca Clavel[4], Roman Krivonos[2], Kaya Mori[1], John Tomsick[4], Shuo Zhang[3]
Institution(s): *1. Columbia Astrophysics Laboratory, 2. IKI, 3. MIT, 4. UC Berkeley*

109.09 – Magnetohydrodynamic Simulations of Black Hole Accretion Flows Using PATCHWORK, a Multi-Patch, multi-code approach

A multi-patch approach to numerical simulations of black hole accretion flows allows one to robustly match numerical grid shape and equations solved to the natural structure of the physical system. For instance, a cartesian gridded patch can be used to cover coordinate singularities on a spherical-polar grid, increasing computational efficiency and better capturing the physical system through natural symmetries. We will present early tests, initial applications, and first results from the new MHD implementation of the PATCHWORK framework.

Author(s): Mark J. Avara[1], Scott Noble[5], Hotaka Shiokawa[2], Roseanne Cheng[4], Manuela Campanelli[1], Julian H. Krolik[3]
Institution(s): *1. Center for Computational Relativity and Gravitation, RIT, 2. Harvard, CfA, 3. Johns Hopkins University, 4. LANL, 5. University of Tulsa*

109.10 – Supermassive blackholes without super Eddington accretion

We explore the X-ray luminosity function at high redshift for active galactic nuclei using an albeit simplified model for mass build-up using a combination of mergers and mass accretion in the gap paradigm (Garofalo et al. 2010). Using a retrograde-dominated configuration we find an interesting low probability channel for the growth of one billion solar mass black holes within hundreds of millions of years of the big bang without appealing to super Eddington accretion (Kim et al. 2016). This result is made more compelling by the connection between this channel and an end product involving active galaxies with FRI radio morphology but weaker jet powers in mildly sub-Eddington accretion regimes. We will discuss our connection between the unexplained paucity of a given family of AGNs and the rapid growth of supermassive black holes, two heretofore seemingly unrelated aspects of the physics of AGNs that will help further understand their properties and evolution.

Author(s): Damian Joseph Christian[1], Matt I Kim[3], David Garofalo[2], Jaclyn D'Avanzo[2], John Torres[1]
Institution(s): *1. California State University, 2. Kennesaw State University, 3. University of Manchester*

109.11 – Self-gravitating fluid tori with charge

We have been developing an analytical approach to study equilibria of self-gravitating charged fluid embedded in the gravitational and magnetic fields of a central body. Our calculations provide a toy-model scenario for gaseous/dusty tori surrounding supermassive black holes in galactic nuclei. While the central black hole dominates the gravitational field and remains electrically neutral, the surrounding material has a non-negligible self-gravitational effect on the torus structure. Moreover, by charging mechanisms it also acquires non-zero electric charge density. These two influences need to be taken into account to achieve a self-consistent picture (based on Trova et al., ApJSS, 226, id. 12, 2016).

Author(s): Vladimir Karas[1], Audrey Trova[3], Jiri Kovar[2]
Institution(s): *1. Astronomical Institute, 2. Silesian University, 3. ZARM — Centre of Applied Space Technology and Microgravity*

109.12 – NuSTAR observations of black hole binary candidates in the Galactic Center and its environs

The recent discovery of a diffuse, hard X-ray emission in the central 10 pc (Perez et al. 2015) interpreted as magnetic cataclysmic variables (Hailey et al. 2017) leaves open the question of whether a sub-dominant population of sources could exist much closer to the supermassive black hole (SMBH), which NuSTAR could not resolve. Here we report the recent NuSTAR observations of two new transient hard X-ray sources within ~ 1 pc of the Galactic Center, which were discovered by Swift. These sources have no known counterparts at other energies. The spectral properties of these sources rule out NS-HMXBs. Continuous monitoring of the Galactic Center by Swift, combined with the known short (<~ 5 year) recurrence time of neutron star LMXBs, strongly suggest that these new transients are black hole binary candidates (BHC). We will present 3-79 keV NuSTAR spectra of these sources that further support a black hole binary interpretation. These new BHCs, combined with at least one other previously discovered BHC near the Galactic Center, hint at a potential substantive black hole population in the vicinity of the SMBH, and we present an estimate of their numbers, given knowledge of the black hole binary giant outburst recurrence times. We also report recent results from the NuSTAR Galactic Legacy Survey of a larger region, ~ 0.7 square degrees, focusing on the search for more BHCs.

Author(s): Charles James Hailey[1], Kaya Mori[1]
Institution(s): *1. Columbia Univ.*

109.13 – Black Hole Variability in MHD: A Numerical Test of the Propagating Fluctuations Model

The variability properties of accreting black hole systems offer a crucial probe of the accretion physics providing the angular momentum transport and enabling the mass accretion. A few of the most telling signatures are the characteristic log-normal flux distributions, linear RMS-flux relations, and frequency-dependent time lags between energy bands. These commonly observed properties are often interpreted as evidence of inward propagating mass accretion rate fluctuations where fluctuations in the accretion flow combine multiplicatively. We present recent results from a long, semi-global MHD simulation of a thin (h/r=0.1) accretion disk that naturally reproduces this phenomenology. This bolsters the theoretical underpinnings of the “propagating fluctuations” model and demonstrates the viability of this process manifesting in MHD turbulence driven by the magnetorotational instability. We find that a key ingredient to this model is the modulation of the effective α parameter by the magnetic dynamo.

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

109.14 – Discovery of a Probable BH-HMXB and Cyg X-1 Progenitor System

We report the discovery of a probable black hole High Mass X-ray Binary (BH-HMXB), a 5.3d single line spectroscopic binary (SB1) HD96670 in the Carina OB association. We initiated a search for such systems for which the O star primary was still on the main sequence, in stark contrast to Cyg X-1 with its evolved supergiant O star companion, since such systems must be ~10-30 times more numerous given their longer lifetimes. HD96670 had been found to be a SB1 with binary period ~5.5d and mass function ~0.125Msun. With a ~150ksec NuSTAR observation of HD96670 over 3 segments, we found a significant detection of a variable source best fit with a PL spectrum with photon index between 2.4 and 2.6 for the brightest vs. faintest observations. Weak 6.4 – 6.7 keV emission was also detected. We conducted extensive optical photometry and spectroscopy to better measure the binary system parameters and have fit the the combined data with an ellipsoidal modulation code (Wilson and Devinney) to find that the binary companion is best fit by a ~4.5 Msun BH accreting from the weak wind primary O star with luminosity Lx ~3 x 10^32 erg/s, which cannot be due to a colliding wind or intrinsic Ostar emission. . A B4V or B5V main sequence star companion can be ruled out by the very low accretion luminosity and lack of colliding wind expected. Full details, including the direct measurement of a triple companion B1V star previously reported (Sanna et al 2014) for HD96670, will appear in two forthcoming papers to be summarized in this talk.

Author(s): Jonathan E. Grindlay[2], Sebastian Gomez[2], Jaesub Hong[2], Shuo Zhang[3], Charles Hailey[1], Kaya Mori[1], John Tomsick[4]
Institution(s): *1. Columbia University, 2. Harvard-Smithsonian, CfA, 3. MIT, 4. University of California Berkeley*

109.15 – Evidence for an extremely energetic jet-base during the June 2015 outburst of V404 Cygni

We present results of V-, R-, and I-band optical photometry of the black hole X-ray binary system V404 Cygni obtained using Wheaton College Observatory's 0.3m telescope, along with strictly simultaneous INTEGRAL and Swift observations, on 2015 June 25 and June 27. These observations were made when V404 Cygni was going through an epoch of violent activity in all wavelengths ranging from radio to gamma-rays. The multiwavelength variability timescale favors a compact emission region, most likely originating in a jet outflow. The simultaneous INTEGRAL/IBIS 20--40 keV light curve obtained on June 27 correlates very strongly with the optical light curve, with no detectable delay between the optical bands as well as between the optical and hard X-rays. The slope of the dereddened spectral energy distribution was roughly flat between the V- and I-bands even though both the optical and the X-ray flux varied by >25x during the run, ruling out an irradiation origin and favoring a jet origin for the observed optical emission. Our observations further suggest that the optically-thick to optically-thin jet synchrotron break was at a frequency larger than that of the V-band, which is quite extreme for X-ray binaries. We conclude that the optical emission originated very close to the base of the jet. Our data, in conjunction with contemporaneous data at other wavelengths presented by other groups, strongly suggest that the jet-base was extremely compact and energetic during this phase of the outburst.

Author(s): Dipankar Maitra[6], John Scarpaci[6], Victoria Grinberg[2], Mark Reynolds[5], Sera Markoff[1], Thomas J. Maccarone[4], Robert I. Hynes[3]
Institution(s): *1. Anton Pannekoek Institute for Astronomy, 2. European Space Research and Technology Centre, 3. Louisiana State Univ., 4. Texas Tech University, 5. Univ. of Michigan, 6. Wheaton College*

109.16 – Spectral and Timing Properties of IGR J17091–3624 in the Rising Hard State During Its 2016 Outburst

We present a spectral and timing study of the NuSTAR and Swift observations of IGR J17091–3624 in the hard state during its outburst in 2016. IGR J17091–3624 is a galactic black hole binary candidate that has been previously observed to display variability patterns similar to GRS 1915+105, despite the apparent faintness compared to its counterpart. Disk reflection features are clearly revealed in the NuSTAR data taken in three epochs. Fitting with relativistic reflection models reveals the accretion disk is truncated during all epochs and the modeling favors a low disk inclination. The source flux increased by ~50% during the observations, the steepening of the spectral continuum is accompanied by a declination in the high energy cut-off. A type-C QPO increasing in frequency is detected in the NuSTAR data. In addition, we find a secondary peak centered at about 2.3 times the fundamental QPO frequency in the power spectra. This unconventional frequency questions the harmonic origin of the feature. We investigate the evolution of the timing and spectral properties on the rising phase of the outburst and discuss its physical implications.

Author(s): Yanjun Xu[1], Fiona Harrison[1], Felix Fuerst[2], Javier Garcia[1], Dom Walton[4], John Tomsick[3]
Institution(s): *1. California Institute of Technology, 2. European Space Astronomy Centre, 3. UC Berkeley/SSL, 4. University of Cambridge*

109.17 – Magnetar-like Activity and Radio Emission Variability from the High Magnetic Field Pulsar PSR J1119-6127

We present results from a high frequency radio monitoring campaign of the high magnetic field pulsar PSR J1119-6127 with the Deep Space Network (DSN) 70 m antenna (DSS-43) in Canberra, Australia, following recently reported magnetar-like activity. Dramatic pulsed radio emission variability was observed over several months at S-band (2.3 GHz) and X-band (8.4 GHz) after an initial disappearance of radio pulsations. The S-band pulse profile evolved from a multiple-peaked structure into a single-peak over several weeks, which is extremely unusual for radio pulsars. We also observed significant differences between the polarized pulse profiles at both S-band and X-band. In addition, pulsed emission variability was observed on shorter timescales, of order tens of minutes, during individual observations.

The spectral index from 2.3 GHz to 8.4 GHz varied between < -4.8(2) to -1.7(2) during times when the multi-peaked pulse profile was most prominent at S-band, which is considerably steeper than the pulsar's inferred spectral index of -0.9(1) from previous measurements between 1.4 GHz and 3.1 GHz. We detected unusually bright, transient X-band pulsations as the S-band pulse profile became single-peaked, which led to a flattening of the spectral index to -0.4(1). This transition is likely further evidence of magnetar-like behavior since this spectral index value agrees remarkably well with measurements from other known radio magnetars, such as XTE J1810-1917, SGR J1745-2900, and PSR J1622-4950. A week later, the spectral index steepened and then flattened from -1.34(7) to -0.95(9) over several days. Bright single pulse events were also detected at S/X-band with peak flux densities exceeding 0.49/0.27 Jy.

Although PSR J1119-6127 is normally a rotation-powered pulsar, it is possible that the decay of the pulsar's strong magnetic field, together with other magnetar-like mechanisms, may be responsible for the observed emission variability. We will discuss how these results could connect magnetars with high-B field pulsars.

Author(s): Aaron B. Pearlman[2], Walid A. Majid[3], Shinji Horiuchi[1], Jonathon Kocz[2], Jonas Lippuner[4], Thomas Allen Prince[2]
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109.18 – Resonant Compton Upscattering Models of Magnetar Hard X-ray Emission and Polarization

Non-thermal quiescent X-ray emission extending between 10 keV and around 150 keV has been seen in about 10 magnetars by RXTE, INTEGRAL, Suzaku and Fermi-GBM. For inner magnetospheric models of such hard X-ray signals, resonant Compton upscattering is anticipated to be the most efficient process for generating the continuum radiation. This is because the scattering becomes resonant at the cyclotron frequency, and the effective cross section exceeds the classical Thomson value by over two orders of magnitude. We present angle-dependent hard X-ray upscattering model spectra for uncooled monoenergetic relativistic electrons injected in inner regions of pulsar magnetospheres. These spectra are integrated over closed field lines and obtained for different observing perspectives. The spectral cut-off energies are critically dependent on the observer viewing angles and electron Lorentz factor. We find that electrons with energies less than around 15 MeV will emit most of their radiation below 250 keV, consistent with the observed turnovers in magnetar hard X-ray tails. Moreover, electrons of higher energy still emit most of the radiation below around 1 MeV, except for quasi-equatorial emission locales for select pulses phases. In such cases, attenuation mechanisms such as pair creation will be prolific, thereby making it difficult to observe signals extending into the Fermi-LAT band. Our spectral computations use new state-of-the-art, spin-dependent formalism for the QED Compton scattering cross section in strong magnetic fields. The emission exhibits strong polarization above around 30 keV that is anticipated to be dependent on pulse phase, thereby defining science agendas for future hard X-ray polarimeters.

Author(s): Matthew G. Baring[4], Zorawar Wadiasingh[3], Peter L. Gonthier[1], Alice Kust Harding[2]
Institution(s): *1. Hope College, 2. NASA's Goddard Space Flight Center, 3. North-West University, 4. Rice University*

109.19 – Millisecond Pulsars and the Galactic Center Excess

Various groups including the Fermi team have confirmed the spectrum of the gamma- ray excess in the Galactic Center (GCE). While some authors interpret the GCE as evidence for the annihilation of dark matter (DM), others have pointed out that the GCE spectrum is nearly identical to the average spectrum of Fermi millisecond pul- sars (MSP). Assuming the Galactic Center (GC) is populated by a yet unobserved source of MSPs that has similar properties to that of MSPs in the Galactic Disk (GD), we present results of a population synthesis of MSPs from the GC. We establish parameters of various models implemented in the simulation code by matching characteristics of 54 detected Fermi MSPs in the first point source catalog and 92 detected radio MSPs in a select group of thirteen radio surveys and targeting a birth rate of 45 MSPs per mega-year. As a check of our simulation, we find excellent agreement with the estimated numbers of MSPs in eight globular clusters. In order to reproduce the gamma-ray spectrum of the GCE, we need to populate the GC with 10,000 MSPs having a Navarro-Frenk-White distribution suggested by the halo density of DM. It may be possible for Fermi to detect some of these MSPs in the near future; the simulation also predicts that many GC MSPs have radio fluxes S_{1400}above 10 �μJy observable by future pointed radio observations. We express our gratitude for the generous support of the National Science Foundation (RUI: AST-1009731), Fermi Guest Investigator Program and the NASA Astrophysics Theory and Fundamental Program (NNX09AQ71G).

Author(s): Peter L. Gonthier[1], Yew-Meng Koh[1], Alice Kust Harding[2], Elizabeth C. Ferrara[2]
Institution(s): *1. Hope College, 2. NASA Goddard Space Flight Center*

109.20 – Energetic X-ray-emitting jets from the fast-moving middle-aged pulsar B2224+65

We present evidence for jets from the nearby pulsar, B2224+65, based on three epochs of Chandra X-ray observations, separated by 6 years from each other. This relatively slow rotating pulsar is well known for its extreme velocity of proper motion and associated "Guitar"-shaped optical nebula in the opposite direction. The main jet-like X-ray-emitting feature is extremely narrow and significantly curved near the pulsar, but further away remains amazingly straight and is directed about 62 degrees away from the nebula, the X-ray emission of which is also detected. We find the consistent proper motions of the pulsar and the feature. The substructure of the feature varies among the epochs, while its spectrum is well characterized by a power law with a photon index of 1.2, is significantly harder than that of the pulsar, and remains remarkably consistent spatially and with the time. These results can be explained most intuitively by ballistic, relativistic, and probably magnetic field-dominated jets from the pulsar, similar to those from active galactic nuclei. Indeed, we also detect the extended X-ray emission from the putative counter-jet, albeit at a much fainter level and a much smaller scale. The luminosity of these features is 7e30 erg/s in the Chandra band, accounting for about 1% of the spin-down energy rate of the pulsar. Because of the flat nonthermal X-ray spectrum, this fraction increases with the photon energy. The total power required to generate the jets is likely greater than 10% of the rate. Much of the acceleration of the particles for the (synchrotron) X-ray emission to energies > 100 TeV likely occurs within the jets, probably via magnetic field re-connection. This jet scenario and the underlying physics can be further tested by a carefully designed X-ray monitoring of the substructure and by a measurement of the radio polarization of the pulsar, as its spin axis is expected to be aligned with the jets. We speculate that the energetic jet ejection from B2224+65 may represent a common phenomenon of pulsars, young and old, and an important source of cosmic-rays. The understanding of the ejection could also shed lights into the nature of extragalactic jets.

Author(s): Q. Daniel Wang[1], Seth Johnson[1]
Institution(s): *1. Univ. of Massachusetts*

109.21 – Understanding the Pulsar High Energy Emission: Macroscopic and Kinetic Models

Pulsars are extraordinary objects powered by the rotation of magnetic fields of order 10^8, 10^12G anchored onto neutron stars and rotating with periods 10^(-3)-10s. These fields mediate the conversion of their rotational energy into MHD winds and at the same time accelerate particles to energies sufficiently high to produce GeV photons. Fermi, since its launch in 2008, has established several trends among the observed gamma-ray pulsar properties playing a catalytic role in the current modeling of the high energy emission in pulsar magnetospheres. We judiciously use the guidance provided by the Fermi data to yield meaningful constraints on the macroscopic parameters of our global dissipative pulsar magnetosphere models. Our FIDO (Force-Free Inside, Dissipative Outside) models indicate that the dissipative regions lie outside the light cylinder near the equatorial current sheet. Our models reproduce the light-curve phenomenology while a detailed comparison of the model spectral properties with those observed by Fermi reveals the dependence of the macroscopic conductivity parameter on the spin-down rate providing a unique insight into the understanding of the physical mechanisms behind the high-energy emission in pulsar magnetospheres. Finally, we further exploit these important results by building self-consistent 3D global kinetic particle-in-cell (PIC) models which, eventually, provide the dependence of the macroscopic parameter behavior (e.g. conductivity) on the microphysical properties (e.g. particle multiplicities, particle injection rates). Our PIC models provide field structures and particle distributions that are not only consistent with each other but also able to reproduce a broad range of the observed gamma-ray phenomenology (light curves and spectral properties) of both young and millisecond pulsars.

Author(s): Constantinos Kalapotharakos[1], Gabriele Brambilla[1], Andrey Timokhin[1], Alice Kust Harding[1], Demos Kazanas[1]
Institution(s): *1. NASA, Goddard Space Flight Center*

109.22 – Pulsar braking: Time dependent moment of inertia?

Pulsars rotate with extremely stable rotational frequency enabling one to measure its first and second time derivatives. These observed values can be combined to the so-called braking index. However observed values of braking index differ from the theoretical value of 3 corresponding to braking by magnetic dipole radiation being the dominant theoretical model. Such a difference can be explained by contribution of other mechanism like pulsar wind or quadrupole radiation, or by time dependency of magnetic field or moment of inertia.

In this presentation we focus on influence of time dependent moment of inertia on the braking index. We will also discuss possible physical models for time-dependence of moment of inertia.

Author(s): Martin Urbanec[1]
Institution(s): *1. Silesian University in Opava*

109.23 – Where Are the R-modes? *Chandra* Observations of Millisecond Pulsars

We present the results of *Chandra* observations of two non-accreting millisecond pulsars PSRs J1640+2224 (J1640) and J1709+2313(J1709), with low inferred magnetic fields in order to constrain their surface temperatures, obtain limits on the amplitude of unstable r-modes in them and make comparisons with similar limits obtained for a sample of accreting LMXB neutron stars (NSs). We detect both pulsars in the X-ray band for the first time. We found upper limits on the global surface temperature of these pulsars that are ~ 3.3 - 4.7 × 10^5 K. These sources are several Gyr old. In all standard cooling models NSs cool to surface temperatures less than 10^4 K in less than 10^7 yr. While we derived upper limits on the surface temperatures of these sources, they appear to be consistent with the values measured for PSR J0437-4715 and J2124-3358. Taken together these results suggest that the surface temperatures of at least some MSPs are significantly higher, given their ages, than standard cooling models would suggest. For pulsars that are inside the r-mode instability window, r-mode dissipation can provide a potential source of reheating.

Author(s): Simin Mahmoodifar[1], Tod E. Strohmayer[1]
Institution(s): *1. NASA/GSFC*

109.24 – The Variable Pulsar Wind Nebula of PSR J1809-1917

Pulsar wind nebulae (PWNe) are sources of nonthermal X-ray emission and prominent sites of particle acceleration. We report on three *Chandra* observations of the PWN created by the young and energetic PSR J1809-1917. We discuss the morphology of the elongated compact nebula (CN), the significant changes in morphology it exhibits over timescales of months, and the connection to possible small-scale jets seen along the elongation axis. The extended PWN exhibits a relatively hard spectrum with no evidence of cooling across the 3-pc extent of the nebula. We discuss the PWN's relation to the nearby HESS J1809-193, the candidate TeV counterpart to the PWN.

Author(s): Noel Klingler[2], Oleg Kargaltsev[2], George G. Pavlov[1], Bettina Posselt[1]
Institution(s): *1. Pennsylvania State University, 2. The George Washington University*

109.25 – The Remarkable Synchrotron Nebula Associated with PSR J1015-5719

We report the discovery of a synchrotron nebula G283.1-0.59 associated with the young and energetic pulsar J1015-5719. Radio observations using the Molonglo Observatory Synthesis Telescope (MOST) and the Australia Telescope Compact Array (ATCA) at 36, 16, 6, and 3 cm reveal a complex morphology for the source. The pulsar is embedded in the "head" of the nebula with fan-shaped diffuse emission. This is connected to a circular bubble structure of 20" radius and followed by a collimated tail extending over 1'. Polarization measurements show a highly ordered magnetic field in the nebula. The intrinsic B-field wraps around the edge of the head and shows an azimuthal configuration near the pulsar, then switches direction quasi-periodically near the bubble and in the tail. Together with the flat radio spectrum observed, we suggest that this system is most plausibly a pulsar wind nebula (PWN), with the head as a bow shock that has a low Mach number and the bubble as a shell expanding in a dense environment, possibly due to flow instabilities. In addition, the bubble could act as a magnetic bottle trapping the relativistic particles. A comparison with other bow-shock PWNe with higher Mach numbers shows similar structure and B-field geometry, implying that pulsar velocity may not be the most critical factor in determining the properties of these systems.

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Author(s): Chi Yung Ng[4], Rino Bandiera[2], Richard Hunstead[3], Simon Johnston[1]
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109.26 – A Multi-wavelength Study of an Isolated MSP Bow Shock

PSR J2124-3358 is the only single MSP known to sport an Halpha bow shock. This shock, now also seen in the UV, encloses an unusual X-ray pulsar wind nebula (PWN) with a long off-axis trail. Combining the X-ray and UV images with AAT/KOALA integral field spectroscopy of the Halpha emission, we have an unusually complete picture of the pulsar's (101 km/s transverse) motion and the latitudinal distribution of its wind flux. These images reveal the 3-D orientation of a hard-spectrum PWN jet and a softer equatorial outflow. Within the context of a thin shock model, we can constrain the total energy output of the pulsar and the neutron star moment of inertia. The IFU spectra show extreme Balmer dominance, which also constrains the nature of the UV shock emission.

Author(s): Roger W. Romani[3], Patrick Slane[2], Andrew Green[1]
Institution(s): *1. Anglo-Australian Observatory, 2. CfA, 3. Stanford Univ.*

109.27 – NuSTAR Hard X-ray Observations of the Energetic Millisecond Pulsars PSR B1821-24, PSR B1937+21, and PSR J0218+4232

We present NuSTAR hard X-ray timing and spectroscopy of the three exceptionally energetic rotation-powered millisecond pulsars PSRs B1821-24, B1937+21, and J0218+4232. By correcting for frequency and phase drifts of the NuSTAR on-board clock we are able to recover the intrinsic hard X-ray pulse profiles of all three pulsars with a resolution down to <15 ms. The substantial reduction of background emission relative to previous broad-band X-ray observations allows us to detect for the first time pulsed emission up to ~50 keV, ~20 keV, and ~25 keV, for the three pulsars, respectively. We conduct phase-resolved spectroscopy in the 0.5 - 79 keV range for all three objects, obtaining the best yet measurements of the broad-band spectral shape and high-energy pulsed emission to date. We find extensions of the same power-law continua seen at lower energies, with no conclusive evidence for a spectral turnover or break. Extrapolation of the X-ray power-law spectrum to higher energies reveals that a turnover in the 100 keV to 100 MeV range is required to accommodate the high energy gamma-ray emission observed with Fermi LAT, similar to the broad-band spectral energy distribution observed for the Crab pulsar.

Author(s): Eric V. Gotthelf[1], Slavko Bogdanov[1]
Institution(s): *1. Columbia Astrophysics Lab.*

109.28 – Do central compact objects have carbon atmospheres?

An understanding of the chemical composition of central compact object (CCO) atmospheres is necessary in order to measure their fundamental physical properties. It has been proposed, based on X-ray spectral modeling, that the CCOs in the Cassiopeia A and G353.6-0.7 supernova remnants have uniform-temperature carbon atmospheres. Here, we show that a single-temperature carbon atmosphere model is capable of fitting the spectra of at least seven of the eight currently known central compact objects, with reasonable values of their radii resulting. However, since two of these CCOs are known from their pulsations to have more complex, multi-temperature surfaces, the good fits of their spectra to a single-temperature carbon atmosphere must be a coincidence. This result argues that spectral modeling of a phase-averaged spectrum alone is insufficient evidence that a neutron star has a carbon atmosphere.

Author(s): Jason Alford[1], Eric V. Gotthelf[1], Jules P. Halpern[1]
Institution(s): *1. Columbia University*

110 – Supernovae and Particle Acceleration Poster Session

110.01 – SuperTIGER: On the Cosmic Ray Charge Frontier

The Super Trans-Iron Galactic Element Recorder (SuperTIGER) was designed to measure significant statistics particularly for cosmic rays (CRs) with charge > 30. These heaviest nuclei are some 10^3-10^5 times rarer than the lighter elements. With the longest science flight to date on a Long Duration Balloon in 2012-13, SuperTIGER has collected >1200 of these rare nuclei and millions of lighter CR events. After the instrument spent two winters in Antarctica, we recovered it and are completing preparations for a second flight. We present results from the first flight, including the highest statistical precision measurements of CR charges from 30-40 to date. We anticipate even greater improvements with our second flight, this coming austral summer, 2017-18 from McMurdo, Antarctica. The results show enhanced numbers of elements formed in massive stars relative to solar system values, and thus give insight into the origin of Galactic CRs, likely in OB associations, and into the atomic processes which accelerate nuclei.

Author(s): Theresa J. Brandt[1]
Institution(s): *1. NASA Goddard Space Flight Center*

110.02 – Cosmic Ray Streaming in Galaxy Clusters

The origin of diffuse radio emission in galaxy clusters remains an open question in astrophysics. This emission indicates the presence of cluster-wide magnetic fields and high energy cosmic ray (CR) electrons. I will discuss how the properties of the observed radio emission in clusters are shaped by different CR transport processes, namely CR streaming. Recent work has shown that fast streaming may turn off radio emission on relatively short time scales - a full treatment of magnetohydrodynamic (MHD) wave damping shows that streaming may be even faster than previously thought in high β environments. I will briefly introduce the physics behind CR transport, and present simple numerical simulations of the Coma cluster that predict radio emission, as well as other observable signatures such as gamma radiation that can differentiate between models for the source of the CR electrons.

Author(s): Joshua Wiener[2], Ellen Gould Zweibel[2], Siang P. Oh[1]
Institution(s): *1. University of California, Santa Barbara, 2. University of Wisconsin, Madison*

110.03 – VERITAS and Fermi-LAT observations of new TeV gamma-ray sources discovered by HAWC

The HAWC (High Altitude Water Cherenkov) observatory recently published their second source catalog (2HWC) with over a year of observations at full sensitivity to gamma rays with energies between hundreds of GeV and tens of TeV. Sixteen of the 39 HAWC sources were found to be at least one degree away from any previously known TeV source, representing exciting targets for further study. Here we report on 12 of these unassociated HAWC sources using observations at higher spatial resolution with both VERITAS and Fermi-LAT. We use 8 years of LAT data at energies above 10 GeV and varying exposures with VERITAS. In the case of 2HWC J1953+294, VERITAS finds weak gamma-ray emission from the region and there is no LAT detection. This new TeV source is associated with the supernova remnant DA 495. For the other unassociated HAWC sources no VERITAS or LAT counterpart is found, but the upper limits from our observations can help to constrain the spectrum and spatial extension of the HAWC sources. Additionally, we studied 2HWC J1930+188 for which VERITAS had previously detected a TeV counterpart associated with the remnant G54.1+0.3. Our updated Fermi-LAT analysis also detects emission from this region, consistent with previous models of a pulsar wind nebula origin. Future multi-instrument studies of new HAWC sources promise to uncover the origins of additional cosmic accelerators.

Author(s): John W. Hewitt[4], Jamie Holder[3], Nahee Park[2], Ignacio F Taboada[1]
Institution(s): *1. Georgia Tech, 2. University of Chicago, 3. University of Delaware, 4. University of North Florida*

110.04 – NuSTAR observations of Galactic TeV gamma-ray sources

We present NuSTAR observations of five Galactic TeV gamma-ray sources. Given its broad 3-79 keV energy band and 2 msec timing resolution, NuSTAR telescope is optimal for probing X-ray emission mechanisms (e.g., Leptonic vs Hadronic scenario) of TeV gamma-ray sources and leading to source identification (e.g., pulsar wind nebula, supernova remnants interacting with molecular clouds), combined with multi-wavelength data. Our targets include a rare TeV gamma-ray binary candidate HESS J1832-093, HESS J1834-0846 including the wind nebula around magnetar SWIFT J1834.9-0846, an enigmatic TeV gamma-ray source HESS J1507-622 located at 3.5 degree off the Galactic Plane and two HAWC sources (2HWC J1928+178 and DA495). Some of these TeV gamma-ray sources were observed as a part of the NuSTAR Galactic Legacy Survey in collaboration with the VERITAS and HAWC teams.

Author(s): Kaya Mori[1], Charles James Hailey[1], Eric V. Gotthelf[1]
Institution(s): *1. Columbia University*

110.05 – Joint Likelihood study of Crab pulsar wind nebula with VERITAS and HAWC

The Crab Pulsar Wind Nebula (PWN) has been generally considered a steady source in the fields of high-energy and very-high-energy astronomy. The Fermi-LAT and AGILE satellites detected Crab PWN flux variations, questioning the steadiness of the Crab PWN emission. Significant flux variability has been observed in the MeV energy regime, whereas only marginal flux variability has been observed in the GeV energy regime. However, no variability has been detected in the TeV energy regime. Several viable models have been proposed to explain this behavior. To constrain these models, more sensitive observations of the Crab PWN are needed.

The HAWC and VERITAS gamma-ray observatories have observed the Crab PWN at energies greater than very-high-energies (E > 100 GeV), and have already published independent spectral measurements from each instrument. However, jointly these two instruments are able to cover the extended energy range from 100 GeV to 100 TeV. In addition, a joint Crab PWN observation is
more sensitive than the observation of either independent instrument. This presentation reports on the progress of the ongoing VERITAS-HAWC joint likelihood study of the Crab PWN energy spectrum. This presentation will also report on the use of simultaneous observations of the Crab PWN to cross-calibrate the energy scale and detection aperture of the two observatories.

Author(s): Anushka Udara Abeysekara[1]
Institution(s): *1. University of Utah*

110.06 – Estimating explosion properties of normal hydrogen-rich core-collapse supernovae

Recent parameterized 1D explosion models of hundreds of core-collapse supernova progenitors suggest that success and failure are intertwined in a complex pattern that is not a simple function of the progenitor initial mass. This rugged landscape is present also in other explosion properties, allowing for quantitative tests of the neutrino mechanism from observations of hundreds of supernovae discovered every year. We present a new self-consistent and versatile method that derives photospheric radius and temperature variations of normal hydrogen-rich core-collapse supernovae based on their photometric measurements and expansion velocities. We construct SED and bolometric light curves, determine explosion energies, ejecta and nickel masses while taking into account all uncertainties and covariances of the model. We describe the efforts to compare the inferences to the predictions of the neutrino mechanim. The model can be adapted to include more physical assumptions to utilize primarily photometric data coming from surveys such as LSST.

Author(s): Ondrej Pejcha[1]
Institution(s): *1. Princeton University*

110.07 – The X-ray Light Curve and CCD Spectra of SN 1978K

We provide an updated X-ray light curve and spectral fits of SN1978K using all available data from ROSAT, ASCA, Suzaku, Chandra, Swift, and XMM. The light curve and spectra cover 25 years of X-ray observations of this object. Spectral fits were applied using two models: absorbed dual optically-thin thermal gas ('vapec') and an absorbed thermal gas and non-equilibrium ionization model ('vapec' + 'vnei'). The soft temperatures cluster around 0.65-0.7 keV for both models. The hard temperatures lie typically in the 2-3 keV range, but Several claims over the years have been made for enhanced abundances: Si, claimed to be detected in a 2003 Chandra observation, is not confirmed. The abundance of He, claimed to be detected in XMM observations, requires more work as it is not consistently detected in all observations. The X-ray light curve shows considerable `bouncing', suggesting a variable circumstellar medium, but uncertainties are not negligible.

Author(s): Eric M. Schlegel[1]
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110.08 – Accretion onto Carbon-Oxygen White Dwarfs as a possible mechanism for growth to the Chandrasekhar Limit

We have continued our studies of accretion onto white dwarfs by following the evolution of thermonuclear runaways (TNRs) on Carbon Oxygen (CO) white dwarfs. We have varied the mass of the white dwarf and the composition of the accreted material. We use the results of the multi-dimensional studies of TNRs in white dwarfs, accreting only Solar matter, which show that sufficient core material is dredged-up by the TNR and then ejected by the explosion to agree with the observations of the ejecta abundances. We have also found that the initial ^{12}C abundance is inversely proportional to the amount of material accreted prior to the TNR. Therefore, we first accrete Solar material and follow the evolution until a TNR occurs. Because the ^{12}C abundance is significantly smaller then if we had initially mixed the accreting gas with the carbon-oxygen core, more matter takes part in the explosion than if we had begun the evolution with the mixed composition. We then instantaneously switch the composition to a mixture with either 25% core material or 50% core material (plus accreted material) and follow the resulting evolution of the TNR. We use our 1D, Lagrangian, hydrodynamic code: NOVA. We report on the results of these new simulations and compare the ejecta abundances to those measured in pre-solar grains that are thought to arise from classical nova explosions. These results will also be compared to recent results with SHIVA (Josè and Hernanz). We find that there are some white dwarf masses where significantly less mass is ejected than accreted during the Classical Nova event and, therefore, the white dwarf is growing in mass as a result of the accretion and in spite of the resulting explosion.
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Author(s): Sumner Starrfield[1], Maitrayee Bose[1], Christian Iliadis[5], William R. Hix[3], Jordi José[4], Margarita Hernanz[2]
Institution(s): *1. Arizona State University, 2. Institute of Space Sciences, 3. Oak Ridge National Laboratory, 4. Universitat Politècnica de Catalunya, 5. University of North Carolina*

110.09 – Comparing Neutron Star Kicks to Supernova Remnant Asymmetries

Supernova explosions are inherently asymmetric and can accelerate new-born neutron stars (NSs) to hundreds of km/s. Two prevailing theories to explain NS kicks are ejecta asymmetries (e.g., conservation of momentum between NS and ejecta) and anisotropic neutrino emission. Observations of supernova remnants (SNRs) can give us insights into the mechanism that generates these NS kicks. In this presentation, we investigate the relationship between NS kick velocities and the X-ray morphologies of 18 SNRs observed with Chandra and ROSAT. We measure SNR asymmetries using the power-ratio method (a multipole expansion technique), focusing on the dipole, quadrupole, and octupole power-ratios. Our results show no correlation between the magnitude of the power-ratios and NS kick velocities, but we find that for Cas A and G292.0+1.8, whose emission traces the ejecta distribution, their NSs are preferentially moving opposite to the bulk of the X-ray emission. In addition, we find a similar result for PKS 1209-51, CTB 109, and Puppis A; however their emission is dominated by circumstellar/interstellar material, so their asymmetries may not reflect their ejecta distributions. Our results are consistent with the theory that NS kicks are a consequence of ejecta asymmetries as opposed to anisotropic neutrino emission. In the future, additional observations to measure NS proper motions within ejecta-dominated SNRs are necessary to constrain robustly the NS kick mechanism.

Author(s): Tyler Holland-Ashford[2], Laura A. Lopez[2], Katie Amanda Auchettl[2], Tea Temim[1], Enrico Ramirez-Ruiz[3]
Institution(s): *1. Space Telescope Science Institute, 2. The Ohio State University, 3. University of California Santa Cruz*

110.10 – Hitomi Observations of the LMC SNR N132D: Fast and Asymmetric Iron-rich Ejecta

We present Hitomi Soft X-ray Spectrometer (SXS) observations of N132D, a young, ~2500 year-old, X-ray bright, O-rich core-collapse supernova remnant in the LMC. Despite a very short observation of only 3.7 ksec, the SXS easily detects the line complexes of He-like S K and Fe K with 16-17 counts in each. The Fe K feature is measured for the first time at high spectral resolution, and we find that the Fe K-emitting material is highly redshifted at ~1200 km/s compared to the local LMC ISM, indicating (1) that it arises from the SN ejecta, and (2) that this ejecta is highly asymmetric, since no corresponding blue-shifted component is found. The S K-emitting material has a velocity consistent with the local LMC ISM, and is likely swept-up ISM material. These results are consistent with spatial mapping of these emission lines with XMM-Newton and Chandra, which show the Fe K concentrated in the interior of the remnant and the S K tracing the outer shell. Most importantly, they highlight the power of high-spectral-resolution imaging observations, and demonstrate the new window that has been opened with Hitomi and will be greatly widened with future missions such as the X-ray Astronomy Recovery Mission (XARM) and Athena.

Author(s): Eric D. Miller[1]
Institution(s): *1. MIT*

110.11 – Freely Expanding X-ray Ejecta Knots in Kepler's Supernova Remnant

Using archival data from the *Chandra X-ray Observatory*, we measure the proper motions and radial velocities of compact X-ray bright knots in Kepler's supernova remnant (SNR). The high speed ejecta knots are morphologically and kinematically distinct from the rest of the ejecta and appear only in specific, limited locations. The highest speed knots show both large proper motions and high radial velocities with estimated space velocities of 10,000 km/s, similar to the typical Si velocity seen in Type Ia supernovae near maximum light. The proper motions of five knots extrapolate back over the age of the remnant to a consistent central position, defining a kinematic center for Kepler's SNR. Our new explosion center agrees well with previous determinations, but suffers less from systematic uncertainty. These five knots are expanding at close to the free expansion rate (expansion indices of $0.75 < m < 1.0$), while other knots show slower speeds and expansion indices consistent with decelerated ejecta knots. The differences in the expansion rates are likely a function of differences in the ambient medium density surrounding Kepler's SNR.

Author(s): John Patrick Hughes[1], Toshiki Sato[2]
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110.12 – The Expansion of the SMC SNR 1E 0102.2-7219

1E 0102.2-7219 (hereafter E0102) is the X-ray brightest supernova remnant (SNR) in the Small Magellanic Cloud. E0102 exhibits a mostly spherical symmetric morphology in the X-ray band, with a bright ring of ejecta emission interior to a mostly filled shell. The X-ray spectrum of E0102 is dominated by strong lines of O, Ne, and Mg, with little or no Fe emission. E0102 is one of a handful of "O-rich" SNRs and is the result of the core collapse supernova. The age of the remnant has been estimated to range between 1,000 and 2,000 yr. E0102 is routinely observed by the Chandra X-ray Observatory as a calibration source. Exploiting Chandra's superb angular resolution, we have measured the expansion of the outer blastwave using these observations at different epochs. Hughes et al. 2000 used one of the first Chandra images of E0102 to compare to archival images of E0102 from the Einstein Observatory and the ROSAT satellite to derive an expansion rate of 0.10% per year and a shock velocity of ~6,000 km/s. This relatively high shock velocity was apparently inconsistent with the temperature of ~0.75 keV derived from the X-ray spectra. Hughes et al. suggested that a possible explanation was that a large fraction of the energy of the shock was going into the acceleration of cosmic rays. Restricting our analysis to include only Chandra observations of the blastwave, we find a significantly lower expansion rate of 0.032% per yr which implies a shock velocity of ~1,975 km/s. This shock velocity is consistent with the temperature derived from the X-ray spectral fits.

Author(s): Paul P. Plucinsky[1], Long Xi[2], Terrance Gaetz[1]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. IHEP, CAS*

110.13 – Expansion and Variability in the Pulsar-Wind Nebula in Kes 75 (G29.7-0.3) with *Chandra*

We report new *Chandra* X-ray observations of the shell supernova remnant (SNR) Kes 75 (G29.7-0.3), containing a pulsar and pulsar-wind nebula (PWN). Expansion of both shell and PWN is apparent across the three epochs, 2000, 2006, and 2016, but brightness and morphology changes of the PWN make a quantitative measurement difficult. One image comparison method gives an expansion rate between 2006 and 2016 of the NW edge of the PWN of about (0.2 -- 0.25)%/yr, for an expansion age $R/(dR/dt)$ of 400 -- 500 yr. Consistent results are obtained between 2000 and 2016. Since 2008, the pulsar has had a period of 328 ms and a braking index n of 2.19 (Archibald et al. 2015), giving a spindown age $t_{sd} = P/ ((n - 1)\ dP/dt)$ of 1230 yr, an upper limit to the true age under the normal assumptions of magnetic-dipole energy loss with constant n (though n has changed from 2.65 to its current value for this pulsar). Our result indicates that the initial spindown time $\tau = t_{sd} - t$ is of order t, the true age. For $t < \tau$, simple models predict the PWN radius to grow as $R^{6/5}$, so that the true age is 1.2 times the expansion age, or about 500 -- 600 yr. For the current braking index, the pulsar's initial luminosity was larger than the current value by a factor of 4 -- 6, while the initial period was within a factor of 2 of its current value. We confirm directly that Kes 75 contains the youngest known PWN in the Galaxy, independent of assumptions about the pulsar spindown. The PWN contains a jet whose structure and brightness have evolved significantly since 2000. The brighter northern part of the jet at the center of the PWN has faded by about 35%, while the southern part is roughly constant in brightness. Changes in morphology of the southern jet may be expansion; if so, a change in position of one feature indicates a velocity of ~0.03*c*, much faster than the PWN as a whole.

Author(s): Stephen P. Reynolds[1], Kazimierz J. Borkowski[1]
Institution(s): *1. North Carolina State Univ.*

110.14 – The Population of Supernova Remnants in M51

The nearby, actively star-forming, nearly face-on spiral galaxy, M51 (NGC 5194/5), has been the site of four supernovae since 1941. As a result it should have a rich population of young supernova remnants (SNRs). Here we describe a search for optical SNRs in M51 among the 298 X-ray sources discovered inside the D25 contour in deep Chandra observations. The search uses interference filter images obtained with the WFC3 on Hubble Space Telescope and more recent images from GMOS on Gemini North. Of 80 emission nebulae identified in the HST images as SNR candidates based on elevated [SII]: Ha ratios compared to HII regions, 40 have X-ray counterparts. The diameters of the SNRs and SNR candidates detected with HST are systematically smaller than seen in SNR populations of other galaxies at comparable distances. However, this is most likely an instrumental effect, which our ongoing analysis of the new GMOS images will correct. At that point, we will be able to make of fair multi-wavelength comparison of the SNR population in M51 with other nearby, actively star-forming spiral galaxies, such as M83 and NGC6946.

Author(s): Knox S. Long[3], William P. Blair[1], K. D. Kuntz[1], P. Frank Winkler[2]
Institution(s): *1. Johns Hopkins University, 2. Middlebury College, 3. STScI*

110.15 – The Northern Rims of SNR RCW 86 - Chandra's Recent Observations and their Implications for Particle Acceleration

The Chandra observations towards the northwest (NW) and northeast (NE) rims of supernova remnant (SNR) RCW 86 reveal great detail about the characteristics of the shocks, particle acceleration and the local environments in these 2 distinct regions. Both the NW and NE of RCW 86 show clear evidence of non-thermal X-ray emission, identified as synchrotron radiation from shock-accelerated electrons with TeV energies, interacting with the compressed, and probably amplified, local magnetic field. Magnetic field amplification (MFA) is broadly believed to result from, and contribute to, cosmic ray acceleration at the shocks of SNRs. However, we still lack a detailed understanding of the particle acceleration mechanism, and with this study we address the connection between the shock properties and ambient medium with MFA. The Chandra observations of RCW 86 allowed us to constrain the magnitude of the post-shock magnetic field in the NE and NW rims by deriving synchrotron filament widths, and also the densities in these regions, using thermal emission co-located with the non-thermal rims. I will discuss our analysis in detail and comment on how MFA appears to be related to certain characteristics of the SNR shock.

Author(s): Daniel Castro[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*

110.16 – SPI Analysis of the Supernova Remnant DEM L71

Supernova remnants are complex, three-dimensional objects; properly accounting for this complexity when modeling the resulting X-ray emission presents quite a challenge and makes it difficult to accurately characterize the properties of the full SNR volume. The SPIES (Smoothed Particle Inference Exploration of Supernova Remnants) project aims to address this challenge by applying a fundamentally different approach to analyzing X-ray observations of SNRs. Smoothed Particle Inference (SPI) is a Bayesian modeling process that fits a population of gas blobs ("smoothed particles") such that their superposed emission reproduces the observed spatial and spectral distribution of photons. We present here the results of an SPI analysis of the Type Ia supernova remnant DEM L71. Among other results, we find that despite its regular appearance, the temperature and other parameter maps exhibit irregular substructure.

Author(s): Kari A. Frank[1], Vikram Dwarkadas[2], David N. Burrows[1], Siti Aisyah Mansoor[1], Ryan M. Crum[1]
Institution(s): *1. Pennsylvania State University, 2. University of Chicago*

110.17 – Using Microlensing to Investigate Macro-Models of the Supernova iPTF16geu

We investigate the difference between macro-model magnifications and the observed brightness of the supernova iPTF16geu, as found in a recent paper by More, Suyu, et al. This group suggested that these discrepancies are, qualitatively, likely due to microlensing. We then analyze the plausibility of attributing this discrepancy to microlensing, and find that the discrepancy is too large to be due to microlensing. This is true whether one assumes knowledge of the luminosity of the supernova or allows the luminosity to be a free parameter. Varying the dark/stellar ratio likewise doesn't help doesn't help. Our next step will be to explore macro-models in which the quadruplicity is due primarily to external shear rather than the ellipticity of the lensing galaxy.

Author(s): Daniel Yahalomi[2], Paul L. Schechter[2], Joachim Wambsganss[1]
Institution(s): *1. Heidelberg University, 2. MIT*

111 – Electromagnetic & Gravitational Transients Poster Session

111.01 – Early GRB afterglows from reverse shocks in ultra-relativistic long-lasting winds

We develop a model of early GRB afterglows with the dominant X-ray contribution from the reverse shock (RS) propagating in highly relativistic magnetized wind of a long-lasting central engine. The model reproduces, in a fairly natural way, the overall trends and yet allows for variations in the temporal and spectral evolution of early optical and X-ray afterglows. The high energy and the optical synchrotron emission from the RS particles occurs in the fast cooling regime; the resulting synchrotron power is a large fraction of the wind luminosity. Thus, plateaus - parts of afterglow light curves that show slowly decreasing spectral power - are a natural consequence of the RS emission. Contribution from the forward shock (FS) is negligible in the X-rays, but in the optical both FS and RS contribute similarly. RS emission in the X-rays and combined FS and RS emission in the optical can explain many of puzzling properties of early GRB afterglows.

Author(s): Maxim Lyutikov[1]
Institution(s): *1. Purdue University*

111.02 – A Unified Model for GRB Prompt Emission from Optical to Gamma-Rays: Exploring GRBs as Standard Candles

We suggest here to replace the historical spectral model (Band function) for the Gamma-Ray Burst (GRB) prompt emission (keV-MeV energy regime) with a new one. We show that the complex GRB spectral shapes are well described with a combination of three separate components: a thermal-like component and two components with non-thermal spectral shapes. For the first time, analysis of GRBs with correlated optical and gamma-ray prompt emission show that our new model describes very accurately the whole broadband spectrum from the optical regime to higher energy gamma-rays. In addition, this new model enables a new luminosity-hardness relation based on one of the non-thermal component showing that GRBs may be standard candle. If statistically confirmed, this relation will be used to (i) constrain the mechanisms powering GRB jets, (ii) estimate GRB distances, (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 on board Swift and Suzaku/WAM. I will discuss here the striking similarities of GRB spectral shapes as well as the possible universality of the proposed luminosity-hardness relation in the context of the new model.

Author(s): Sylvain Guiriec[1]
Institution(s): *1. George Washington University*

111.03 – Host galaxies are the obscurers of Gamma-ray bursts

The luminous, high-energy emission of gamma-ray bursts (GRBs) makes them efficient probes of the high-redshift universe. The origin of the obscuration of gamma-ray burst afterglow is still unclear. We study the afterglows metal column densities along the line-of-sight of all Swift-detected long GRBs with an improved hierarchical Bayesian analysis methodology. We characterise follow-up biases and side-step them using SHOALS, an unbiased sub-sample with highly complete follow-up. That survey also measures Spitzer host masses. Overall, the column densities shows little redshift evolution but a significant correlation with host stellar mass. A simple geometrical model explains the width and shape of the column density distribution and the trend with galaxy mass correlation. Our findings implicate the host's galaxy-scale metal gas as the dominant obscurer. From a galaxy evolution perspective, our study places new constraints on the metal gas mass inside galaxies at z=0.5-4. We compare these with modern cosmological simulations (Illustris and EAGLE) and discuss implications for the obscuration of other sources inside high redshift galaxies, such as active galactic nuclei.

Author(s): Johannes Buchner[1], Steve Schulze[1], Franz E. Bauer[1]
Institution(s): *1. PUC*

111.04 – A Study of the Gamma-Ray Burst Fundamental Plane

Long gamma-ray bursts (GRBs) with a plateau phase in their X-ray afterglows obeys a three-dimensional (3D) relation (Dainotti et al. 2016), between the rest-frame time at the end of the plateau, Ta, its corresponding X-ray luminosity, La, and the peak luminosity in the prompt emission, Lpeak, an extension of the two-dimensional Dainotti relation. This 3D relation identifies a GRB fundamental plane whose existence we here confirm. We extend the original analysis with X-ray data untill July 2016 gathering 183 Swift GRBs with afterglow plateaus and known redshifts. We compare several GRB categories, such as shorts with extended emission, SEE, X-ray Flashes, GRBs associated with SNe, 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. The relation planes for each of these categories are not statistically different from the gold fundamental plane, with the exception of the SEE, which are hence identified as a physically distinct class of objects. 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. Additionally, we tested this 3D relations by using GRBs observed at high energy, namely the peak luminosity values derived by the Fermi-Gamma Ray Burst Monitor (GBM). The 3D relation is also confirmed for GRBs observed by the GBM, thus showing its independence from the energy range. Furthermore, 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.

Author(s): Maria Dainotti[5], Xavier Hernandez[6], Sergey Postnikov[1], Shigehiro Nagataki[3], P. T. O'Brien[2], Richard Willingale[2], Stephanie Striegel[4]
Institution(s): *1. ARRRC International, 2. Leicester, 3. RIKEN, 4. San Jose State University, 5. Stanford University, 6. University of Mexico, UNAM*

111.05 – The latest news from LIGO and Virgo

After the ground-breaking detections of gravitational waves from merging binary black holes in the first Advanced LIGO observing run, there is still a great deal to be learned about the population and astrophysics of gravitational-wave sources. The second observing run (O2) will be drawing to a close around the time of the HEAD Meeting, and the Virgo detector in Italy is on a track to observe jointly with LIGO in the latter part of the run. I will share the latest news about the status and performance of the detectors as well as details about any candidate or confirmed events from the O2 run that may be published by the time of the HEAD Meeting.

Author(s): Peter S. Shawhan[1]
Institution(s): *1. Univ. of Maryland*

111.06 – Dynamical Formation of Black Hole Binaries in Globular Clusters

Theoretical predictions for black holes in field populations of binary stars are extremely sensitive to the assumptions of stellar evolution, leading, for example, to predicted merger rates for binary black holes that span several orders of magnitude. But in dense stellar environments such as globular clusters, binary black holes form by well-understood gravitational interactions. We will present an overview of recent theoretical work on the dynamical formation of black hole binaries based on realistic N-body simulations of globular clusters. By calibrating theoretical models against observed properties of globular clusters, we find that the mergers of dynamically formed binaries could eventually be detected by Advanced LIGO at a rate of at least ~ 100 per year, potentially dominating the overall detection rate of gravitational wave sources. Dynamical processes in globular clusters can also form very naturally the black hole X-ray binaries that have been tentatively identified recently in many Milky Way and extragalactic globular clusters.

Author(s): Frederic A. Rasio[2], Sourav Chatterjee[2], Kyle Kremer[2], Carl Rodriguez[1]
Institution(s): *1. MIT, 2. Northwestern Univ.*

111.07 – Hunting Multimessenger Transients with the IBIS Instrument on board *INTEGRAL*

The growing number of detections of gravitational wave events and high-energy neutrinos has spurred searches for electromagnetic (EM) counterparts across the spectrum. Observations at X-ray/gamma-ray energies provide one of the best opportunities to detect an EM signature for one of these events. In the case of compact object mergers involving a neutron star, a GRB-like event may be detected, though the LIGO/VIRGO collaboration has yet to detect any such mergers. Also, GRBs are a possible origin for Ultra High Energy Cosmic Rays (UHECRs) and may be associated with high-energy neutrinos. The gamma-ray observatory *INTEGRAL* is well equipped to detect the EM counterparts of multimessenger transient events with its good sensitivity from X-rays to gamma-rays (up to ~10 MeV) combined with a large field-of-view (~400 cm^2 with >50% sensitivity). At soft gamma-ray energies, it can also behave as an all-sky monitor as its high-energy detectors are unshielded from large parts of the sky. Hereafter, we discuss the main characteristics of the *INTEGRAL*/IBIS soft gamma-ray detector (PICsIT) and its sensitivity regarding the detection of EM counterparts of multimessenger transients above ~200 keV.

Author(s): James Rodi[2], Angela Bazzano[2], Carlo Ferrigno[1], Sandro Mereghetti[3], Lorenzo Natalucci[2], Volodymyr Savchenko[1], Pietro Ubertini[2]
Institution(s): *1. INTEGRAL Science Data Centre, 2. Istituto di Astrofisica e Planetologia Spaziali - INAF, 3. Istituto di Astrofisica Spaziale e Fisica Cosmica*

112 – Physics of Hot Plasmas Poster Session

112.01 – High resolution spectral signatures of X-ray emission following charge exchange recombination between highly charged iron and neutral helium, molecular hydrogen and molecular nitrogen: A comparison between theory and experiment

We have used the LLNL electron beam ion trap EBIT-I and a NASA/GSFC quantum microcalorimeter to measure the X-ray emission following charge exchange recombination between highly charged Fe25+ and Fe 26+ and neutral helium, molecular hydrogen, and molecular nitrogen. The ~ 5 eV energy resolution of the microcalorimeter has made it possible to measure and resolve n to 1 K-shell transitions from up to n = 14. We compare the measurements to a model based on the Landau-Zener theory and also the models found in SPEX and APEC. Our results include relative intensities of the 1P1 resonance line to the 3S1 forbidden line, commonly referred to as lines w and z. These results are especially useful for interpreting spectra from celestial sources measured with XARM's Resolve and ATHENA's X-IFU. These data have also proved useful in the interpretation of Hitomi's SXS spectrum of the Perseus cluster.

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.

Author(s): Gregory V. Brown[1], Renata Cumbee[2], Liyi Gu[3], Richard L. Kelley[2], Caroline Kilbourne[2], Maurice A. Leutenegger[2], Frederick S Porter[2], Peter Beiersdorfer[1]
Institution(s): *1. LLNL, 2. NASA/GSFC, 3. RIKEN*

112.02 – Laboratory measurements compellingly support a charge-exchange mechanism for the "Dark matter" ~3.5 keV X-ray line

A mysterious X-ray signal at 3.5 keV from nearby galaxies and galaxy clusters recently sparked tremendous interest in the scientific community and has given rise to a tide of publications attempting to explain the origin of this line [1]. It has been hypothesized that the signal is the result of decaying sterile neutrinos – a potential dark matter particle candidate – presumably based on the fact that this X-ray line is not available in the standard spectral databases and models for thermal plasmas. Cautiously, Gu et al. [2] have pointed out an alternative explanation for this phenomenon: charge exchange between bare ions of sulfur and atomic hydrogen. Their model shows that X-rays should be emitted at 3.5 keV by a set of S^{15+} transitions from $n \geq 9$ to the ground states, where n is the principle quantum number.

We tested this hypothesis in the laboratory by measuring K-shell X-ray spectra of highly ionized sulfur ions following charge exchange with gaseous molecules in an electron beam ion trap. We produced bare S^{16+} and H-like S^{15+} ions and let them capture electrons in collisions with molecules while recording X-ray spectra. The 3.5 keV transition clearly shows up in the charge-exchange induced spectrum under a broad range of conditions. The inferred X-ray energy of 3.47 ± 0.06 keV is in full accord with both the astrophysical observations and theoretical calculations, and confirms the novel scenario proposed by Gu [2]. Taking the experimental uncertainties and inaccuracies of the astrophysical measurements into account, we conclude that the charge exchange between bare sulfur and hydrogen atoms can outstandingly explain the mysterious signal at around 3.5 keV [3].

[1] E. Bulbul et al., Astrophys. J. **13**, 789 (2014)
[2] L. Gu et al., A & A **L11**, 584 (2015)
[3] C. Shah et al., Astrophys. J. **833,** 52 (2016)

Author(s): Chintan Shah[1], Sven Bernitt[1], Stepan Dobrodey[1], René Steinbrügge[1], Liyi Gu[2], Jelle S. Kaastra[2], José R. Crespo Lopez-Urrutia[1]
Institution(s): *1. Max Planck Institute for Nuclear Physics, 2. SRON Netherlands Institute for Space Research*

112.03 – H- and He-like Charge-Exchange Induced X-ray Emission due to Ion Collisions with H, He, and H_2

When a hot plasma collides with a cold neutral gas interactions occur between the microscopic constituents including charge exchange (CX). CX is a process in which an electron can be transferred from a neutral atom or molecule into an excited energy level of an ion. Following this transfer, the excited electron relaxes to lower energy levels, emitting X-rays. This process has been established as a primary source of X-ray emission within our solar system, such as when the solar wind interacts with cometary and planetary atmospheres, and outside of our solar system, such as in the hot outflows of starburst galaxies.

Since the CX X-ray emission spectrum varies greatly with collision velocity, it is critical that realistic CX data are included in X-ray spectral models of astrophysical environments in which CX might be significant in order to correctly estimate the ion abundance and plasma velocities. Here, line ratios and spectra are computed using theoretical CX cross sections obtained with the multi-channel Landau-Zener, atomic-orbital close-coupling, and classical-trajectory Monte Carlo methods for a variety of collision energies relevant to various astrophysical environments. Collisions of bare and H-like C, N, O, Ne, Mg, Al, Si, P, S, and Cl ions are shown with H, He, and H_2 as the neutral collision targets. An X-ray model using line ratios for C-Si ions is then performed within XSPEC for a region of the Cygnus Loop supernova remnant for 8 collision energies in order to highlight the variation in CX spectral models with collision energy.

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Author(s): Renata Cumbee[2], Patrick Mullen[1], Ansley Miller[3], David Lyons[3], Robin L. Shelton[3], David R. Schultz[4], Phillip C. Stancil[3], Maurice A. Leutenegger[2]
Institution(s): *1. University of Illinois, 2. NASA/GSFC, 3. University of Georgia, 4. University of North Texas*

112.04 – Polarization of resonantly excited X-ray lines

For a wide range of temperatures, resonantly captured electrons with energies below the excitation threshold are the strongest source of X-ray line excitation in hot plasmas containing highly charged Fe ions. The angular distribution and polarization of X-rays emitted due to these processes were experimentally studied using an electron beam ion trap. The electron-ion collision energy was scanned over the *KLL* dielectronic, trielectronic, and quadruelectronic recombination resonances of $Fe^{18+..24+}$ and $Kr^{28+..34+}$ with an exemplary resolution of ~6 eV. The angular distribution of induced X-ray fluorescence was measured along and perpendicular to the electron beam propagation direction [1]. Subsequently, the polarization of X-ray fluorescence was also measured using a novel Compton polarimeter [2, 3]. The experimental data reveal the alignment of the populated excited states and exhibit a high sensitivity to the relativistic Breit interaction [2, 4]. We observed that most of the transitions lead to polarization, including hitherto-neglected trielectronic and quadruelectronic recombination channels. Furthermore, these channels dominate the polarization of the prominent *K*α X-rays emitted by hot anisotropic plasmas in a wide temperature range. The present experimental results comprehensively benchmark full-order atomic calculations carried out with the FAC [5] and RATIP [6] codes. We conclude that accurate polarization diagnostics of hot anisotropic plasmas, e.~g., of solar flares and active galactic nuclei, and laboratory fusion plasmas of tokamaks can only be obtained under the premise of careful inclusion of relativistic effects and higher-order resonances which were often neglected in previous works [1]. The present experiments also demonstrate the suitability of the applied technique for accurate directional diagnostics of electron or ion beams in hot plasmas [7].

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[3] S. Weber et al., Rev. Sci. Instr. **86**, 093110 (2015)
[4] P. Amaro et al., Phys. Rev. A **95**, 022712 (2017)
[5] M. F. Gu, Can. Phys. J **86**, 675 (2008)
[6] S. Fritzsche, Comput. Phys. Commu. **183**, 1525-1559 (2012)
[7] C. Shah et al., submitted (2017)

Author(s): Chintan Shah[2], Pedro Amaro[4], René Steinbrügge[2], Sven Bernitt[2], Stephan Fritzsche[1], Andrey Surzhykov[3], José R. Crespo Lopez-Urrutia[2], Stanislav Tashenov[4]
Institution(s): *1. Friedrich-Schiller-Universität Jena, 2. Max Planck Institute for Nuclear Physics, 3. Physikalisch-Technische Bundesanstalt, 4. Physikalisches Institut*

112.05 – Resonant scattering as a sensitive diagnostic of current collisional plasma models

Resonant scattering is a subtle process that suppresses fluxes of some of the brightest optically thick X-ray emission lines produced by collisional plasmas in galaxy clusters and massive early-type galaxies. The amplitude of the effect depends on the turbulent structure of the hot gas, making it a sensitive velocity probe. It is therefore crucial to properly model this effect in order to correctly interpret high resolution X-ray spectra. Our measurements of resonant scattering with XMM-Newton Reflection Grating Spectrometer in giant elliptical galaxies and with Hitomi in the center of Perseus Cluster show that the potentially rich inference from this effect is limited by the uncertainties in the atomic data underlying plasma codes such as APEC and SPEX. Typically, the effect is of the order of 10-20%, while the discrepancy between the two codes is of similar order or even higher. Precise knowledge of the emissivity and oscillator strengths of lines emitted by Fe XVII and Fe XXV, as well as their respective uncertainties propagated through plasma codes are key to understanding gas dynamics and microphysics in giant galaxies and cluster ICM, respectively. This is especially crucial for massive ellipticals, where sub-eV resolution would be needed to measure line broadening precisely, making resonant scattering an important velocity diagnostic in these systems for the foreseeable future. In this poster, I will summarize current status of resonant scattering measurements and show how they depend on the assumed atomic data. I will also discuss which improvements are essential to maximize scientific inference from future high resolution X-ray spectra.

Author(s): Anna Ogorzalek[4], Irina Zhuravleva[4], Steven W. Allen[4], Ciro Pinto[1], Norbert Werner[2], Adam Mantz[4], Rebecca Canning[4], Andrew C Fabian[1], Jelle S. Kaastra[3], Jelle de Plaa[3]
Institution(s): *1. Institute of Astronomy, 2. MTA-Eotvos University, 3. SRON Netherlands Institute for Space Research, 4. Stanford University*

113 – Spectral Timing & Data Analysis Poster Session

113.01 – Cross-matching with the Chandra Source Catalog

Cross-matching the Chandra Source Catalog (CSC) with other catalogs presents considerable challenges, since the Point Spread Function (PSF) of the Chandra X-ray Observatory varies significantly over the field of view. For the second release of the CSC we have developed a cross-match tool that is based on the Bayesian algorithms by Budavari, Heinis, and Szalay (ApJ 679, 301 and 705, 739), making use of the error ellipses for the derived positions of the detections.
However, calculating match probabilities only on the basis of error ellipses breaks down when the PSFs are significantly different. Not only can bonafide matches easily be missed, but the scene is also muddied by ambiguous multiple matches. These are issues that are not commonly addressed in cross-match tools. We have applied a satisfactory modification to the algorithm that, although not perfect, ameliorates the problems for the vast majority of such cases.
A separate issue is that as the number of overlapping catalogs increases, the number of matches to be considered increases at an alarming rate, requiring procedural adjustments to ensure that the cross-matching finishes within a Hubble time. We have found a solution among graph theory algorithms.
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.

Author(s): Arnold H. Rots[2], Dan Nguyen[2], Tamas Budavari[1], Douglas J. Burke[2], Francesca M. Civano[2], Roger Hain[2]
Institution(s): *1. Johns Hopkins University, 2. Smithsonian Astrophysical Observatory*

113.02 – XSTAR Code and Database Status

The XSTAR code is a simulation tool for calculating spectra associated with plasmas which are in a time-steady balance among the microphysical processes. It allows for treatment of plasmas which are exposed to illumination by energetic photons, but also treats processes relevant to collision-dominated plasmas. Processes are treated in a full collisional-radiative formalism which includes convergence to local thermodynamic equilibrium under suitable conditions. It features an interface to the most widely used software for fitting to astrophysical spectra, and has also been compared with laboratory plasma experiments. This poster will describe the recent updates to XSTAR, including atomic data, new features, and some recent applications of the code.

Author(s): Timothy R. Kallman[1]
Institution(s): *1. NASA's GSFC*

113.03 – A Machine-learning approach to classification of X-ray sources

Chandra and XMM-Newton X-ray observatories have serendipitously detected a large number of Galactic sources. Although their properties are automatically extracted and stored in catalogs, most of these sources remain unexplored. Classifying these sources can enable population studies on much larger scales and may also reveal new types of X-ray sources. For most of these sources the X-ray data alone are not enough to identify their nature, and multiwavelength data must be used. We developed a multiwavelength classification pipeline (MUWCLASS), which relies on supervised machine learning and a rich training dataset. We describe the training dataset, the pipeline and its testing, and will show/discuss how the code performs in different example environments, such as unidentified gamma-ray sources, supernova remnants, dwarf galaxies, stellar clusters, and the inner Galactic plane. We also discuss the application of this approach to the data from upcoming new X-ray observatories (e.g., eROSITA, Athena).

Author(s): Jeremy Hare[3], Oleg Kargaltsev[3], Blagoy Rangelov[2], George Pavlov[1], Bettina Posselt[1], Igor Volkov[4]
Institution(s): *1. Pennsylvania State University, 2. Texas State University, 3. The George Washington University, 4. University of Maryland*

113.04 – Scrutinizing the unresolved x-ray background in the CDFS field via transdimensional sampling

We analyse the Chandra Deep Field South (CDFS) data using a novel inference framework called probabilistic cataloging, where fair samples are taken from the posterior distribution of the catalog space of point sources in the field consistent with the merged CDFS exposure. This requires constructing a Markov chain of samples via transdimensional proposals involving births and deaths as well as within-model proposals. Our point source model is also hierarchical, allowing the shape of the flux distribution of the point sources to be inferred simultaneously. By marginalizing over point sources below the detection threshold, robust uncertainty estimates can be placed on the flux and color distribution of Active Galactic Nuclei (AGNs) as well as the normalization and spectrum of the truly isotropic background. We validate our method using simulated deep Chandra exposures and show that the isotropic background emission can be constrained at the 10% level, which is a result that takes into account its covariance with unresolved AGNs and the particle background of Chandra. We compare our method to results derived from fluctuation analyses, i.e., study of the 1-point function of photon counts across the image, and discuss how our results relate to the AGN population synthesis models.

Author(s): Tansu Daylan[1], Richard Feder-Staehle[1], Douglas P. Finkbeiner[1]
Institution(s): *1. Harvard University*

113.05 – New Swift UVOT data reduction tools and AGN variability studies

The efficient slewing and flexible scheduling of the Swift observatory have made it possible to conduct monitoring campaigns that are both intensive and prolonged, with multiple visits per day sustained over weeks and months. Recent Swift monitoring campaigns of a handful of AGN provide simultaneous optical, UV and X-ray light curves that can be used to measure variability and interband correlations on timescales from hours to months, providing new constraints for the structures within AGN and the relationships between them. However, the first of these campaigns, thrice-per-day observations of NGC 5548 through four months, revealed anomalous dropouts in the UVOT light curves (Edelson, Gelbord, et al. 2015). We identified the cause as localized regions of reduced detector sensitivity that are not corrected by standard processing. Properly interpreting the light curves required identifying and screening out the affected measurements.

We are now using archival Swift data to better characterize these low sensitivity regions. Our immediate goal is to produce a more complete mapping of their locations so that affected measurements can be identified and screened before further analysis. Our longer-term goal is to build a more quantitative model of the effect in order to define a correction for measured fluxes, if possible, or at least to put limits on the impact upon any observation. We will combine data from numerous background stars in well-monitored fields in order to quantify the strength of the effect as a function of filter as well as location on the detector, and to test for other dependencies such as evolution over time or sensitivity to the count rate of the target. Our UVOT sensitivity maps and any correction tools will be provided to the community of Swift users.

Author(s): Jonathan Gelbord[1], Rick Edelson[2]
Institution(s): *1. Spectral Sciences, Inc., 2. University of Maryland, College Park*

113.06 – Balance in the NASA Astrophysics Program

The Decadal studies are usually instructed to come up with a “balanced program” for the coming decade of astrophysics initiatives, both on the ground and in space. The meaning of “balance” is left up to the Decadal panels. One meaning is that there should be a diversity of mission costs in the portfolio. Another that there should be a diversity of science questions addressed. A third is that there should be a diversity of signals (across electromagnetic wavebands, and of non-em carriers).

It is timely for the astronomy community to debate the meaning of balance in the NASA astrophysics program as the “Statement of Task” (SoT) that defines the goals and process of the 2020 Astrophysics Decadal review are now being formulated.

Here I propose some ways in which the Astro2020 SoT could be made more specific in order to make balance more evident and so avoid the tendency for a single science question, and a single mission to answer that question, to dominate the program.

As an example of an alternative ambitious approach, I present a proof-of-principle program of 6, mostly “probe-class” missions, that would fit the nominal funding profile for the 2025-2035 NASA Astrophysics Program, while being more diverse in ambitious science goals and in wavelength coverage.

Author(s): Martin Elvis[1]
Institution(s): *1. Harvard-Smithsonian CfA*

113.07 – Hawk-Eyes on Science and in Space

For more than ten years the successful and well received outreach programs, Hawk-Eyes On Science and Hawk-Eyes in Space, have brought the excitement of science demonstrations to Iowans of all ages. However, the creation of a successful, sustainable outreach program requires the coordination of many aspects. In many respects, the demonstrations and hands-on activities are of secondary importance when weighed against the problems of funding, transportation, staffing, etc. In addition to showing examples of demonstrations that we use, I will also focus on a few of the problems and some of the solutions that we have found while coordinating our long running outreach programs at the University of Iowa Department of Physics and Astronomy.

Author(s): Lillie Durow[1]
Institution(s): *1. University of Iowa*

X-ray SIG Meeting

114 – Advances in Bayesian Astrostatistics: Applications to High-Energy Astrophysics

114.01 – Quantifying Discovery in Astrophysics: Frequentist and Bayesian Perspectives

Statistical discovery questions in physics and astrophysics often involve mathematical subtleties that mean standard methods (e.g., chi-square) are inappropriate and can lead to misleading results. At the same time Bayesian and classical statistical techniques can lead researchers to differing conclusions. Moreover modern computational strategies are typically infeasible under extreme discovery criteria (4 sigma or more). This talk explores the statistical challenges that arise in the quantification of discovery and suggests a strategy that combines Bayesian and classical statistical techniques to tackle these challenges.

Author(s): David A van Dyk[1]
Institution(s): *1. Imperial College London*

114.02 – Calibration Concordance by Multiplicative Shrinkage with Applications to Astronomical Instruments

Calibration data for instruments used for astrophysical measurements are often obtained by observing different astronomical objects (a.k.a. sources) with well-understood characteristics simultaneously with different instruments. The proper concordance among different instruments is a vital issue in such calibration data sets. This requires a careful modeling of the mean signals, the intrinsic source differences, and measurement errors. Although in high-energy astronomy the data are Poisson photon counts, they are large enough (typically >>30) to justify an approximate log-normal model, or a more general log-t model. This has the advantage of permitting imperfection in the multiplicative mean modeling to be captured by the residual variance. The estimator then takes an analytically tractable form of power shrinkage, with a half-variance adjustment to ensure an unbiased multiplicative mean model on the original scale. We apply our method to several data sets, from a combination of observations of active galactic nuclei (AGN) and spectral line emission from the supernova remnant E0102, obtained with a variety of X-ray telescopes such as Chandra, XMM-Newton, Suzaku, and Swift. We demonstrate that the proposed model gives important guidance for astrophysicists to adjust for disagreements between different instruments and various sources. The data are compiled by the International Astronomical Consortium for High Energy Calibration (IACHEC) researchers.

Author(s): XiaoLi Meng[2], Yang Chen[2], Xufei Wang[2], David A van Dyk[3], Herman L. Marshall[4], Vinay Kashyap[1]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. Harvard University, 3. Imperial College London, 4. Massachusetts Institute of Technology*

114.03 – MCMC in XSPEC

I wil describe the current MCMC implementation in XSPEC and its use for Bayesian analysis, discuss some of the challenges, and consider future enhancements.

Author(s): Keith A. Arnaud[1]
Institution(s): *1. CRESST/UMd/GSFC*

114.04 – The Whole is Greater Than the Sum of its Parts: Better (Population) Inference Through Bayesian Hierarchical Modeling

In high-energy astrophysics, a single spectrum or light curve rarely tells the whole story. Instead, we learn about the physics of black holes by observing how their spectra change with time, or we aim to draw conclusions about dense matter physics from a population of neutron stars and their light curves. Traditionally, however, much more thought is devoted to modeling individual spectra or light curves independently than to sample inference methods. If the sample is governed by a single underlying physical process, this approach ignores important information, and makes us less confident in our results than we ought to be. Here Bayesian hierarchical models offer a principled, self-consistent solution: they allow us to combine multiple observations to explicitly infer properties of the whole sample, often with more precision than modeling each observation separately would have yielded. In this talk, I will give an overview of the state-of-the-art in Bayesian hierarchical modeling and associated sampling methods in high-energy astrophysics, as well as show some recent advances in using this approach in both X-ray spectroscopy and timing.

Author(s): Daniela Huppenkothen[1]
Institution(s): *1. New York University*

114.05 – BXA: Practical model comparison and robust parameter estimation for X-ray spectroscopy

Choosing between several models is an everyday problem in the analysis of X-ray spectra. Is it justified to add a spectral line? Is physical effect A present? Do I need to replace this component with a more detailed physical model? Until now, the methods commonly applied in practice have been limited.
BXA allows practical Bayesian model comparison for spectral models, by connecting the Multinest algorithm to xspec/sherpa. I will demonstrate how to use BXA for model selection between different obscurer geometries of AGN, show that this approach is more sensitive than likelihood ratio thresholds and present how to calibrate false selection rates.
BXA also allows robust parameter estimation, because contrary to MCMC approaches, BXA easily deals with multiple solutions and automatically converges to a well-defined end point.
Finally, I will briefly discuss how to infer about the populations behind limited samples with Hierarchical Bayesian inference.

Author(s): Johannes Buchner[1]
Institution(s): *1. PUC*

200 – AGN I

200.01 – High-Resolution Multi-Wavelength Observations of AGN Obscurers and Absorbers

The talk will include highlights from several of our recent multi-wavelength campaigns on AGN Outflows.
New results from XMM-Newton, HST, NuStar and Swift will be shown.
The fast, obscurers - transient on different time scales - which are observed in NGC 5548, and just this year in NGC 3783, will be
compared with the steady, ionized absorbers that are prevalent in Seyfert galaxies.
Their different roles in the AGN system and contributions to galactic feedback will be discussed and quantified.
The challenge of measuring the variability of these absorbers will be exemplified at high resolution, and the best constraints will be presented.
Finally, simultaneous X-ray and radio monitoring of NGC 7469 will be shown and the connection between the X-ray and radio source in this AGN will be demonstrated.

Author(s): Ehud Behar[1]
Institution(s): *1. Technion*

200.02 – Constraining the Launching Radius of the Ionized Outflow in NGC 3783

Ionized absorption in the X-ray spectra of Seyfert galaxies displaying the hallmarks of outflowing material has been well-known since the advent of some of the earliest X-ray satellite missions. Now using an optimized extraction technique, we present some of the highest S/N and resolution Chandra spectra to date of NGC 3783. We model the spectra in a physically-motivated and self-consistent way with the photoionization code XSTAR and find that including broadened re-emission provides a better fit than absorption alone. By assuming that the broadening of the emission lines is due to the Keplerian rotation of the accretion disk, we are able to place constraints on the launching radius—a necessary parameter for estimating the mechanical power of the wind.

Author(s): Robyn Nicole Smith[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland*

200.03 – The Ultra-fast Outflows of PG 1211+143

Prior X-ray studies of the Narrow Line Seyfert 1 galaxy PG 1211+143 utilizing the XMM-Newton Reflection Gratings Spectrometer have revealed evidence for highly ionized, outflowing wind components with velocities on the order of 10% the speed of light. In this work we describe deep (430 ksec) X-ray observations with the higher spectral resolution Chandra High Energy Transmission Gratings that were performed contemporaneously with Hubble Space Telescope Cosmic Origins Spectrograph (HST-COS) and Jansky Very Large Array observations. We confirm the presence of an ultra-fast outflow with velocity ~6% of the speed of light in the PG 1211+143 rest frame, as well as the presence of narrow, low velocity fluorescent and He-like Fe emission lines (consistent with unresolved Fe features in recent NuSTAR observations of PG 1211+143). We use the multi-wavelength spectra to construct an ionizing spectral energy distribution for photoionization calculations, and successfully describe the outflow as a warm absorber with ionization parameter $\log_{10}(\xi/\mathrm{erg\ s^{-1}}) \sim 2.8$ and column $N_H \sim 3 \times 10^{21}\ \mathrm{cm^{-2}}$. Furthermore, the UV spectra obtained with HST-COS reveal a broad, blue-shifted Lyman-alpha feature, also with an outflow velocity of ~0.06 c, which could be a potential counterpart to the X-ray ultra-fast outflow.

Author(s): Michael Nowak[3], Ashkbiz Danehkar[1], Gerard A. Kriss[5], Julia C. Lee[2], Randall K. Smith[4], Joseph Neilsen[3]
Institution(s): *1. Center for Astrophysics, 2. Harvard, 3. MIT Kavli Institute, 4. Smithsonian Astrophysical Observatory, 5. STScI*

200.04 – Ultrafast outflows in Super-Eddington Tidal Disruption Events

The disruption of a star from the strong tidal forces of a supermassive black hole can cause the stellar debris to fall back towards the black hole at super Eddington rates. Efficient circularization of the debris can lead to the formation of an accretion disc with luminosities close to or potentially exceeding Eddington limit. Most super-Eddington accretion flow models (including recent magnetohydrodynamic simulations) predict large scale height, optically thick equatorial winds at relativistic velocities. In this talk, we will present observational results from two of the most well-observed X-ray emitting Tidal Disruption Events, Swift J1644+57 and ASASSN-14li. Both of these objects show evidence for massive outflows at tens of percent of the speed of light. The outflow in Swift J1644+57 was detected via blue shifted emission and reverberation of the iron K alpha line, and ASASSN-14li shows a potential P Cygni profile of the OVIII line. We will discuss the constraints that these observations put on the geometry of the super-Eddington accretion flows in tidal disruption events.

Author(s): Erin Kara[1]
Institution(s): *1. University of Maryland*

200.05 – Microlensing Constraints on Quasar Spins and X-ray Reflection Regions

Gravitational microlensing provides a unique probe of the innermost parts of quasar accretion disks, close to the event horizon of supermassive black holes. Using Chandra monitoring data of six lenses from two Large Programs in Cycles 11 and 14/15, we identified two microlensing effects that can be used to constrain black hole spins and X-ray reflection regions for high redshift quasars. The first effect is the excess iron line equivalent widths of lensed quasars compared to normal AGN, and the second is the distribution of iron line peak energies of lensed quasars. A microlensing analysis of the iron line equivalent widths prefers high spin values and very steep iron line emissivity profiles for quasars at z~2. We will also discuss the prospect of measuring quasar spins with microlensing using the next generation of X-ray telescopes.

Author(s): Xinyu Dai[1]
Institution(s): *1. Univ. of Oklahoma*

200.06 – AGN Coronae in the NuSTAR era

The hard X-ray power-law continuum in AGN originates in a magnetically-powered corona above the centre of the accretion disc. Recent observations, particularly from NuSTAR, show that the corona is radiatively compact and has a temperature typically in the range of 30 to 300 keV. The position of AGN within the compactness-temperature plane suggests that they are controlled by electron-pair production. We explore hybrid plasmas and high magnetic compactness as necessary in order to account for the observed behaviour.

Author(s): Andrew Fabian[1], Anne Lohfink[1]
Institution(s): *1. University of Cambridge*

201 – The First Black Holes in the Universe

201.01 – High-redshift AGN in the Chandra Deep Fields: paving the way for Lynx

Deep X-ray surveys provide unprecedented access to the population of accreting super-massive black holes (SMBH) at high redshift. We will present our recent results on the 3<z<6 AGN population in the 7 Ms CDF-S and 2 Ms CDF-N, the deepest X-ray surveys to date. Analyzing both individually-detected sources and the stacked (i.e. average) emission from undetected galaxies, we put tight constraints on quantities such as the obscured AGN fraction and the number density of z>3 AGN. In particular, we derived a large fraction (50-80%) of heavily-obscured (logNH>23) AGN, which does not evolve significantly from z=3 to 6. In contrast to low-redshift findings, the obscured AGN fraction does not appear to decrease significantly at high luminosities. We also found that the mass growth of SMBH at high-redshift is dominated by the fast and short AGN phase, with a possible low-rate, continuous accretion in galaxies playing a secondary role. Finally, we will show our findings on the high-redshift AGN X-ray luminosity function, focussing in particular on the slope of the faint end, accessible only by the deepest X-ray surveys. This is particularly important to assess the contribution of AGN to the cosmic reionization. All of these results will be placed in the context of SMBH seeds formation and growth, and comparison with expectations from simulations will be provided. We will also discuss how future X-ray missions like Lynx and Athena, together with new optical facilities like JWST and WFIRST, will boost our knowledge of the SMBH formation and evolution in the early universe.

Author(s): Fabio Vito[1], W. Niel Brandt[1]
Institution(s): *1. Pennsylvania State University*

201.02 – Theoretical Models for the Growth of the First Black Holes

Massive black holes (BHs) inhabit local galaxies, from massive to dwarf galaxies. BH formation modeling therefore need to explain the entire population of BHs that we observe today, including the less massive ones found in dwarf galaxies. We have developed an implementation of BH formation in the hydrodynamical with mesh refinement code Ramses, where BHs form in dense, low-metallicity environments, and BH masses are computed one-by-one on-the-fly. This self-consistent method allows us to study the distribution of BHs in a cosmological context and their evolution over cosmic time. Supernova feedback (SN) is thought to play an important role in regulating star formation in low-mass galaxies. We therefore test different SN feedback implementations, and find that SNe are able to stunt and regulate BH growth at early times. Our simulated BH population with stronger SN feedback is in good agreement with observational constraints, such as bolometric and hard X-ray BH luminosity function at high redshift, as well as with the number of observational high redshift AGN candidates. We use our cosmological simulation to draw predictions on the BH population at high redshift.

Author(s): Melanie Habouzit[1]
Institution(s): *1. Center for Computational Astrophysics*

201.03 – Optimal Conditions for the Cosmological Growth of Black Hole Seeds

The first black hole seeds formed when the Universe was younger than 500 Myr and played an important role in the growth of early (z=7) supermassive black holes. Much progress has been made in recent years in understanding their formation, growth and observational signatures, but many questions remain unanswered and we are yet to detect these sources.

Black holes with masses on the order of 10 billion solar masses, close to the theoretical maximum mass, are observed from z=7 to z=0. To grow these behemoths in the early Universe, accretion at least at the Eddington rate needs to be sustained for the entire cosmic time down to z=7, making their formation unlikely.

I describe a new work that theoretically investigates the optimal conditions allowing a black hole seed to sustain Eddington or super-Eddington accretion rates for an extended period of cosmic time. We take into account angular momentum transport, small and large spatial scale conditions to ensure that these black hole seeds have always access to a continuous stream of gas to sustain their rapid growth.

Author(s): Fabio Pacucci[1]
Institution(s): *1. Yale University*

201.04 – Identifying First X-ray Sources

Detection of X-ray emission from the first population of sources could constrain formation of super-massive black holes and properties of the first population of X-ray binaries. However, direct observations of high redshift populations require large integration times and are highly biased because only the brightest objects at high redshifts can be detected. A useful measurement is of the unresolved cosmic X-ray background (CXB) which constrains both the luminosity of the most common objects and clustering of these sources. An alternative way to probe the first population of X-ray sources is via its effect on the environment. These sources had a dramatic effect on the Universe heating and mildly ionizing the intergalactic medium. One of the most efficient tools to probe the thermal state of the IGM at high redshifts is the radio signal of neutral hydrogen with the rest-frame wavelength of 21 cm. In my talk I will discuss how cross-correlation between CXB and the 21 cm signal can be used to constrain the first population of X-ray sources.

Author(s): Anastasia Fialkov[1]
Institution(s): *1. Harvard University*

201.05 – Using gravitational waves to track the growth of black holes by mergers

Discoveries by LIGO have stunningly validated the long-promised astronomical science that can be provided by gravitational wave observations. Though these first observations are of merging stellar mass black holes, the waveforms they have measured are identical (modulo simple scalings in mass and frequency) to those that are expected from mergers of black holes with millions or billions of solar masses. In this talk, I will review the astronomical case for high redshift black hole binaries. I will describe how measurements of the gravitational waves such binaries produce by a detector like LISA can be used to track the growth and evolution of black holes through mergers. This will complement the information provided by other methods which are sensitive to their growth by accretion. Working together, such measurements will provide a complete picture of the growth of massive black holes in our universe.

Author(s): Scott A. Hughes[1]
Institution(s): *1. MIT*

202 – The Very High Energy Universe as Viewed with VERITAS and HAWC

202.01 – Surveying the TeV Sky with the High Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory

HAWC is a continuously operating (>95% on-time), wide field-of-view (~2 sr) observatory located at 14000' above sea level in Puebla, Mexico. HAWC observes ~2/3 of the sky each day and has produced a map from the first year and a half of operations with ~ 40 sources of which about one quarter were previously unknown. Most of the sources are within the Galactic plane; however, the two extragalactic blazars Mrk 421 and Mrk 501 are also strongly detected. Within the region surveyed by HAWC are many dark matter rich objects, such as dwarf spheroidal galaxies, and these HAWC data place the strongest constraints to date on annihilating or decaying dark matter with masses >10 TeV. The Crab nebula is detected in this map at > 100 σ and is each day ~ 5σ. The HAWC data are searched in real time for transient sources. HAWC monitors the same sky as gamma-ray satellites (Fermi), gravity-wave (LIGO) detectors and neutrino observatories (IceCube) allowing for multi-wavelength and multi-messenger observations.

Author(s): Brenda L. Dingus[1]
Institution(s): *1. LANL*

202.02 – Very High Energy Astrophysics with VERITAS

The VERITAS imaging atmospheric Cherenkov telescope array is the most sensitive observatory of the northern sky at 1 TeV and has studied over 50 gamma-ray sources including supernova remnants, pulsars and their nebulae, binary systems, and active and starburst galaxies. We review some recent VERITAS results on the follow-up of newly discovered HAWC sources and other sources of cosmic rays.

Author(s): Philip Kaaret[1]
Institution(s): *1. Univ. of Iowa*

202.03 – VHE Sources: X-ray and TeV connections

I will provide an overview of the population of galactic VHE sources focusing on the properties of their lower-energy (X-ray and radio) counterparts and identification of the physical nature of the VHE sources. I will go over the limiting factors hampering the identifications and describe a multiwavelength machine-learning approach to counterpart searches. I will pay particular attention to the relic pulsar wind nebulae population as it is the largest and most difficult to identify.

Author(s): Oleg Kargaltsev[1], Jeremy Hare[1], George G. Pavlov[2]
Institution(s): *1. George Washington University, 2. Pennsylvania State University*

202.04 – Multi-Wavelength Extragalactic Science (High-Energy Astronomy with HAWC, VERITAS, Fermi)

The pioneering exploration of the high-energy regime enabled in the 90's by the EGRET telescope on the Compton Gamma Ray Observatory revealed the existence of a great variety of objects that populates the gamma-ray Universe. At the same time, it pointed out the necessity for future missions in this regime to have as desirable capabilities a wide field-of-view, improved sensitivity and better source localisation, among others. About a decade after, this has been possible with the inauguration of the Very Energetic Radiation Imaging Telescope Array System (VERITAS) and the launch of the wide field-of-view Fermi Large Area Telescope (LAT). Another 10 years after, the HAWC (High Altitude Water Cherenkov) observatory began its operations building on the successful heritage of these previous instruments. HAWC is now an invaluable player along with VERITAS and Fermi-LAT, to give an unprecedented complementary view in the multi-wavelength survey of the high-energy extragalactic phenomena.

Author(s): Sara Buson[1]
Institution(s): *1. NASA/GSFC*

202.05 – Nuggets of Gold in the Era of VHE Gamma-Ray Astronomy

Over the last two decades, the field of very high energy gamma-ray astrophysics has burgeoned from a fledgling experimental foray into a thriving astronomical discipline, replete with well over 100 known TeV-band sources spanning a variety of object classes. This short review summarizes some of the advances in understanding pertaining to supernova remnants, pulsar wind nebulae, the Crab pulsar and blazars that are afforded by VHE detections of them using imaging atmospheric Cerenkov telescopes. Some pressing questions remain unanswered concerning these sources, and the talk will briefly discuss prospects for probing them with the much anticipated Cerenkov Telescope Array.

Author(s): Matthew G. Baring[1]
Institution(s): *1. Rice University*

204 – Mid-Career Prize Talk - X-ray Winds from Black Holes, Jon Miller

204.01 – X-ray Winds from Black Holes

Across the mass scale, high-resolution X-ray spectroscopy has transformed our view of accretion onto black holes. The ionized disk winds observed from stellar-mass black holes may sometimes eject more mass than is able to accrete onto the black hole. It is possible that these winds can probe the fundamental physics that drive disk accretion. The most powerful winds from accretion onto massive black holes may play a role in feedback, seeding host bulges with hot gas and halting star formation. The lessons and techniques emerging from these efforts can also reveal the accretion flow geometry in tidal disruption events (TDEs), an especially rich discovery space. This talk will review some recent progress enabled by high-resolution X-ray spectroscopy, and look at the potential of gratings spectrometers and microcalorimeters in the years ahead.

Author(s): Jon M. Miller[1]
Institution(s): *1. Univ. of Michigan*

205 – ISM & Galaxies

205.01 – Latest Observations of M31 with the Fermi Large Area Telescope: A Galactic Center Excess in Andromeda?

The Fermi LAT has opened the way for comparative studies of cosmic rays (CRs) and high-energy objects in the Milky Way (MW) and in other, external, star-forming galaxies. We revisited the gamma-ray emission in the direction of M31 using more than 7 yr of LAT Pass 8 data in the energy range 0.1-100 GeV. M31 is detected with a significance of nearly 10 sigma and the source is observed to be extended with a 4 sigma significance. Its spectrum is consistent with a power law. The spatial distribution of the emission is consistent with a uniform brightness disk over the plane of sky and no offset from the center of M31, but nonuniform intensity distributions cannot be excluded. The flux from M31 appears confined to the inner regions of the galaxy and does not fill the plane of the galaxy or extend far from it. The gamma-ray signal is not correlated with regions rich in gas or star-formation activity suggesting that the emission is not interstellar in origin, unless the energetic particles radiating in gamma rays do not originate in recent star formation. Alternative and nonexclusive interpretations are that the emission results from a population of millisecond pulsars dispersed in the bulge and disk of M31 by disrupted globular clusters or from the decay or annihilation of dark matter particles, similar to what has been proposed to account for the so-called Galactic center excess found in Fermi-LAT observations of the MW.

Author(s): Xian Hou[2], Pierrick Martin[1]
Institution(s): *1. IRAP, CNRS, 2. Yunnan Observatories*

205.02 – The Galactic Center observed with H.E.S.S.

<!--StartFragment-->The Galactic Center region has been a prime target region for the H.E.S.S. Imaging Atmospheric Cherenkov Telescope Array observations since data taking started in 2003. H.E.S.S. has revealed the presence of a very high energy gamma-ray diffuse emission in the central 200 pc, in addition to the detection of a point like source coincident with the supermassive black hole SgrA*. With more than 250 hours of H.E.S.S. data and the continuous improvement of the analysis techniques, a detailed morphology and spectral analysis of the region is now possible.

We will report on the new characterisation of the spectrum of the central source down to 100 GeV energies taking advantage of the H.E.S.S. II data, obtained after the inclusion of the large 28-meter CT5 telescope in the array centre. We will present the recent discovery of a powerful cosmic PeVatron accelerator at the center of our Galaxy as well as a new characterization of the diffuse gamma-ray emission in the central 200 pc of our Galaxy through a detailed morphology study. By analysing the nature of the various components of this emission, the existence of a strong cosmic-ray gradient and thus the presence of a strong cosmic-ray accelerator at the very centre of our Galaxy was found. We will also report on the discovery of an additional point-like source HESS J1746-285 in this region possibly associated with the pulsar wind nebula candidate G0.13-0.11. <!--EndFragment-->

Author(s): Lea Jouvin[1]
Institution(s): *1. Université Paris Diderot*

205.03 – Probing Galactic Center Cosmic-Rays in the X-ray Regime

The central few hundred parsecs of the Galaxy harbors 5-10% of the molecular gas mass of the entire Milky Way. This central molecular zone exhibits 6.4 keV Fe Kα line and continuum X-ray emission with time-variability. The time-variable X-ray emission from the gas clouds is best explained by light echoes of past X-ray outbursts from the central supermassive black hole Sgr A*. However,MeV-GeV cosmic-ray particles may also contribute to a constant X-ray emission component from the clouds, through collisional ionization and bremsstrahlung. Sgr B2 is the densest and most massive cloud in the central molecular zone. It is the only known gas cloud whose X-ray emission has kept fading over the past decade and will soon reach a constant X-ray level in 2017/2018, and thus serves as the best probe for MeV-GeV particles in the central 100 pc of the Galaxy. At the same time, the Fe Kα emission has also been discovered from molecular structures beyond the central molecular zone, extening to ~1 kpc from the Galactic center. The X-ray reflection scenario meets challenges this far from the Galactic center, while the MeV-GeV cosmic-ray electrons serve as a more natural explanation. Our studies on Sgr B2 and the large-scale moleuclar structures will for the first time constrain the MeV-GeV particles in the Galactic center, and point to their origin: whether they rise from particle acceleration or dark matter annihilation.

Author(s): Shuo Zhang[1], Frederick K. Baganoff[1], Esra Bulbul[1], Eric D. Miller[1], Mark W. Bautz[1]
Institution(s): *1. MIT*

205.04 – The evolution of low-luminosity AGN and X-ray binaries in star-forming galaxies

Numerous studies on the connection between X-ray AGN and their host galaxies are building up a detailed picture of the physical mechanisms regulating AGN activity and star formation as a function of redshift. Most of these works have focused on moderate and high-luminosity AGN with LX > 10^{42} erg/s, and only recently the lower-luminosity AGN population in dwarf and early-type galaxies was investigated using stacking techniques. In this talk, we present the redshift evolution of low-luminosity AGN (LX < 10^{42} erg/s) in star-forming galaxies at z = 0.1-5 in the COSMOS field, using a sample of 123,000 star-forming galaxies and the Chandra COSMOS Legacy survey data providing 160 ks of exposure for each source. Stacking the X-ray data of galaxies grouped into z, mass (M), and star formation rate (SFR) bins, we are sensitive to average X-ray luminosities between 10^{40} erg/s at z = 0.2 and 10^{42} erg/s at z = 3, two orders of magnitude fainter than X-ray detected sources. At these luminosities, X-ray binaries (XRBs) make a significant, or even dominant, contribution to the total X-ray emission, and some studies suggest that their emission evolves with redshift, but different redshift dependences for LX/SFR and LX/M of XRBs have been measured. Our stacking analysis reveals that the average LX of star-forming galaxies is higher than expected based on local XRB relations and that this luminosity excess increases with redshift. This excess may be due to low-luminosity AGN activity, the redshift evolution of XRB populations, or both. We explore these different scenarios, using X-ray hardness ratios, and trends between LX, SFR, and M to untangle the relative contributions of XRBs and AGNs. Such measurements provide valuable constraints on models of binary stellar evolution as well as BH seeds models, and are important for informing future mission studies. We compare our results to other studies of the redshift evolution of XRBs and the observed evolution of higher luminosity AGN.

Author(s): Francesca Fornasini[1], Francesca M. Civano[1], Giuseppina Fabbiano[1], Martin Elvis[1]
Institution(s): *1. Harvard-Smithsonian CfA*

205.05 – A Deep NuSTAR Survey of M31: Compact object types in our Nearest Neighbor Galaxy

X-ray binaries (XRBs) trace young and old stellar populations in galaxies, and thus star formation rate and star formation history/stellar mass. X-ray emission from XRBs may be responsible for significant amounts of heating of the early Intergalactic Medium at Cosmic Dawn and may also play a significant role in reionization. Until recently, the E>10 keV (hard X-ray) emission from these populations could only be studied for XRBs in our own galaxy, where it is often difficult to measure accurate distances and thus luminosities. We have observed M31 in 4 NuSTAR fields for a total exposure of 1.4 Ms, covering the young stellar population in a swath of the disk (within the footprint of the Panchromatic Hubble Andromeda Treasury (PHAT) Survey) and older populations in the bulge. We detected more than 100 sources in the 4-25 keV band, where hard band (12-25 keV) emission has allowed us to discriminate between black holes and neutron stars in different accretion states. The luminosity function of the hard band detected sources are compared to Swift/BAT and INTEGRAL-derived luminosity functions of the Milky Way population, which reveals an excess of luminous sources in M31 when correcting for star formation rate and stellar mass.

Author(s): Ann E. Hornschemeier[3], Daniel R. Wik[3], Mihoko Yukita[3], Andrew Ptak[3], Tonia M. Venters[3], Bret Lehmer[6], Thomas J. Maccarone[5], Andreas Zezas[4], Fiona Harrison[1], Daniel Stern[2], Benjamin F. Williams[7], Neven Vulic[3]
Institution(s): *1. Caltech, 2. JPL/Caltech, 3. NASA GSFC, 4. SAO, 5. Texas Tech University, 6. University of Arkansas, 7. University of Washington*

205.06 – The Circum-Galactic Medium of MASsive Spirals (CGM-MASS): XMM-Newton observations of the hot CGM

<!--StartFragment-->We present the analysis of the XMM-Newton data of the Circum-Galactic Medium of MASsive Spirals (CGM-MASS) sample of six extremely massive spiral galaxies in the local Universe. After removing X-ray bright point-like sources and prominent diffuse X-ray features not associated with the galaxy, we study the spatial and spectral properties of the hot halo gas. All the CGM-MASS galaxies have diffuse X-ray emission from hot gas detected above the background extending ~(30-100)kpc from the galactic center. The radial soft X-ray intensity profile of hot gas can be fitted with a β-function with the slope typically in the range of β=0.35-0.55. β of massive spiral galaxies

[the CGM-MASS galaxies, the Milky Way (MW), and the massive spiral galaxy NGC1961 and NGC6753] are in general consistent with X-ray luminous elliptical galaxies with similar hot gas luminosity and temperature. The measured β of the CGM-MASS galaxies is also consistent with those predicted from a hydrostatic isothermal gaseous halo. The hot gas temperature of lower mass galaxies is systematically higher than the Virial temperature, but massive spiral galaxies have hot gas temperature in general comparable to the Virial temperature, indicating the importance of gravitational heating in these massive systems. We homogenize and compare the halo X-ray luminosity measured for the CGM-MASS galaxies and other disk galaxies. Typically <1% of the SNe energy has been detected in X-ray around quiescent massive spiral galaxies (CGM-MASS, MW), but this X-ray radiation efficiency increases to ~5% for NGC1961 and NGC6753, which have higher SFR. The ratio between the radiative cooling timescale and the free fall timescale is much larger than the critical value of ~10 throughout the entire halo of all the CGM-MASS galaxies, indicating the inefficiency of gas cooling and precipitation in the CGM. The hot CGM in these massive spiral galaxies is thus most likely in a hydrostatic state, with the feedback material mixed with the CGM, instead of escaping out of the halo or falling back to the disk.<!--EndFragment-->

Author(s): Jiang-Tao Li[4], Joel N. Bregman[4], Daniel Wang[3], Robert Crain[1], Michael Anderson[2], Shangjia Zhang[4]
Institution(s): *1. Liverpool John Moores University, 2. Max-Planck Institute for Astrophysics, 3. University of Massachusetts, 4. University of Michigan*

206 – First Results from NICER: X-ray Astrophysics from the International Space Station

206.01 – NICER Mission Status, On-orbit Payload Capabilities, and Early Results

Between its anticipated launch to the International Space Station in June 2017 and the time of this meeting, the Neutron star Interior Composition Explorer (NICER) will have undergone an intensive on-orbit checkout and calibration campaign, settling into its science operations phase. To kick off this Special Session, we provide a brief overview of the NICER mission, the verified capabilities of the payload and its X-ray Timing Instrument (XTI), and early data returns that demonstrate NICER's scientific potential. We introduce the mission's program of neutron star investigations (to be described in more detail by other speakers in this Session), plans for release of NICER data through the HEASARC, and opportunities for the broader community's participation through Discretionary Time allocations and an eventual Guest Observer program.

Author(s): Zaven Arzoumanian[1], Keith Gendreau[1], Craig Markwardt[1]
Institution(s): *1. NASA/GSFC*

206.02 – Neutron Star Radius and Mass Determinations Using NICER

Determining the masses and radii of neutron stars is important, not only for understanding the astronomical properties of these stars, but also for understanding the physical properties of the cold dense matter within them. The NICER mission will measure the masses and radii of several rotation-powered pulsars by fitting pulse waveform models to observations of the soft X-ray waveforms produced by the rotation of hot spots located near their magnetic polar caps. In this talk I will describe how these measurements will be made, the results we expect, and how these results will be used to constrain the properties of cold dense matter.

Author(s): Sharon Morsink[1]
Institution(s): *1. Univ. of Alberta*

206.03 – Planning and Early Observations for Neutron Star X-ray Binary Science with NICER

NICER presents great opportunities to study accreting neutron stars in our Galaxy, including phenomena on both their surfaces and accretion disks. We discuss the NICER Science Team's observing plans, and present some early results. Exploiting the strengths of NICER's X-ray Timing Instrument, spectroscopic features such as lines and edges from photo-ionized reflection off the disk, are explored jointly with timing signatures, including high frequency quasi periodic oscillations, to form a powerful probe of these systems. Of particular interest are Type I X-ray bursts, which are powered by nuclear fusion of material accreted onto the stellar surface. NICER's large effective area and high throughput enable new, detailed studies of these bursts in the soft X-ray band (<2 keV). Bursts peak in this band during their brightest phase, when the photospheric radius expands. Metal-rich ashes may be exposed, producing absorption features in the spectrum. By observing strong radius expansion, such as the recently discovered superexpansion, we aim to measure the gravitational redshift of these spectral features, and constrain the neutron star's compactness. Furthermore, the timing signal in the soft band may reveal burst oscillations, potentially expanding the number of accreting neutron stars with a measured spin frequency, as well as potentially other pulsation modes. Finally, we search for deviations of the burst spectrum from a Planck distribution due to scattering in the atmosphere, reflection off the accretion disk, and other previously inaccessible phenomena. Burst reflection is expected to dominate the soft X-ray signal, tracing the impact of a burst on its surroundings, including changes in the ionization state and geometry of the disk as well as the corona. It is a unique experiment of accretion disk dynamics, that is enabled by the combination of detailed spectral and timing observations of bursts.

Author(s): Laurens Keek[1]
Institution(s): *1. University of Maryland/NASA GSFC*

206.04 – NICER View of Magnetars and Young Pulsars

Neutron star Interior Composition ExploreR (NICER), a NASA Explorer Mission of Opportunity, will be attached in early June in 2017 to the International Space Station (ISS). NICER's large effective area in soft X-rays and high time resolution will provide not only precise measurements of neutron star masses and radii but also powerful diagnostics for studying surface and magnetospheric emission from a variety of magnetized neutron stars. The NICER Magnetar & Magnetosphere (M&M) working group selected initial targets from magnetars, high-B pulsars, isolated neutron stars, and rotation-powered pulsars with a total time allocation of 1.5 Ms. Our program includes regular monitoring of faint transient magnetars and high-B pulsars, spectral studies of absorption features in nearby isolated neutron stars, and study of spectral components and radio/X-ray correlations of rotation-powered pulsars. Here we report our observation plan and early results from the NICER M&M group.

Author(s): Teruaki Enoto[3], Victoria M. Kaspi[4], Alice Kust Harding[6], Tolga Guver[1], Walid A. Majid[2], Wynn C.G. Ho[8], Bennett Link[5], Kent S. Wood[7], Zaven Arzoumanian[6],Keith Gendreau[6]
Institution(s): *1. Istanbul University, 2. Jet Propulsion Laboratory, 3. Kyoto University, 4. McGill University, 5. Montana State University, 6. NASA/GSFC, 7. Naval Research Laboratory, 8. University of Southampton*

206.05 – A NICER X-ray Sky: X-ray Astrophysics Beyond Neutron Stars with NICER

NICER is the new premier X-ray timing instrument onboard the ISS, having been installed this summer. I will present some of NICER's early results on microquasars, AGN, CVs, and other (non-neutron star) sources and share an overview of the NICER science team's plan for exploring our X-ray sky.

Author(s): James F. Steiner[1]
Institution(s): *1. MIT Kavli Institute*

300 – Black Holes Across the Mass Spectrum

300.01 – Perils at the heart of the Milky Way: Systematic effects for studying low-luminosity accretion onto Sgr A*

The supermassive black hole at the center of our galaxy, Sgr A*, is surprisingly under-luminous. This problem has motivated a host of theoretical models to explain low-level radiatively inefficient accretion flows onto compact objects. We discuss how the Galactic Center sight line, which is optically thick to the scattering of soft X-rays (tau ~ 5), affects high resolution studies of the accretion flow around Sgr A*. X-ray light from compact objects in the dense GC environment is scattered by foreground dust, producing scattering echoes that are time delayed relative to the X-ray source's light curve. We discuss the scattering halo of SWIFT J174540.7-290015, which underwent the brightest X-ray outburst within 30" of Sgr A*. Preliminary fits to the scattering halo suggest that a small amount of foreground dust, within 250 pc of the GC, affects the X-ray surface brightness profile within 10" of any GC point source. The associated time delay is on the order of several hours, which is important for understanding the quiescent accretion flow of Sgr A*. We take advantage of the Chandra Galactic Center XVP dataset to explore the effect of the interstellar medium on the inferred characteristics of Sgr A*.

Author(s): Lia Corrales[6], Brayden Mon[3], Daryl Haggard[3], Frederick K. Baganoff[4], Gordon Garmire[1], Nathalie Degenaar[2], Mark Reynolds[5]
Institution(s): *1. Huntingdon Institute for X-ray Astronomy, 2. Institute of Astronomy, University of Cambridge, 3. McGill, 4. MIT, 5. University of Michigan, 6. University of Wisconsin - Madison*

300.02 – Stellar tidal disruption flares provide evidence for a black hole event horizon

The tidal disruption of a star by a massive black is expected to yield a luminous flare of thermal emission. Optical transient surveys have collected about two dozen similar-looking nuclear transients that are consider examples of these stellar tidal disruption flares (TDFs). However, explaining the observed properties of these events within the tidal disruption paradigm is challenging. For example, there is no consensus on the origin of the optical emission. This theoretical ambiguity leaves open the possibility that the flares we call TDFs are instead due to a completely different process, such a nuclear supernovae or accretion disk instabilities. Fortunately, the number of discovered TDFs recently became large enough to test a fundamental prediction of the stellar tidal disruption paradigm. At high black hole mass (greater than $10^8\,M_{\odot}$), the star will be swallowed whole before being disrupted. Using a recently compiled catalog of candidate TDFs with black hole mass measurements, plus a careful treatment of selection effects in this flux-limited sample, we robustly detect a suppression of flares from high-mass black holes. This dearth of observed TDFs from the upper end of the black hole mass distribution is naturally explained by suppression due the event horizon and implies a moderate mean spin of these black holes (a > 0.5). Conversely, if we start by assuming that current TDF candidates are indeed due to stellar tidal disruptions, our sample can be used to constrain the existence of naked singularities.

Author(s): Sjoert Van Velzen[1]

Institution(s): *1. Johns Hopkins University*

300.03 – Ultraviolet Spectroscopy of Tidal Disruption Flares

When a star passes within the sphere of disruption of a massive black hole, tidal forces will overcome self-gravity and unbind the star. While approximately half of the stellar debris is ejected at high velocities, the remaining material stays bound to the black hole and accretes, resulting in a luminous, long-lived transient known as a tidal disruption flare (TDF). In addition to serving as unique laboratories for accretion physics,
TDFs offer the hope of measuring black hole masses in galaxies much too distant for resolved kinematic studies.

In order to realize this potential, we must better understand the detailed processes by which the bound debris circularizes and forms an accretion disk. Spectroscopy is critical to this effort, as emission and absorption line diagnostics provide insight into the location and physical state (velocity, density, composition) of the emitting gas (in analogy with quasars). UV spectra are particularly critical, as most strong atomic features fall in this bandpass, and high-redshift TDF discoveries from LSST will sample rest-frame UV wavelengths.

Here I present recent attempts to obtain UV spectra of tidal disruption flares. I describe the UV spectrum of ASASSN-14li, in which we detect three classes of features: narrow absorption from the Milky Way (probably a high-velocity cloud), and narrow absorption and broad (2000-8000 km s^{-1}) emission lines at or near the systemic host velocity. The absorption lines are blueshifted with respect to the emission lines by 250-400 km s^{-1}. Due both to this velocity offset and the lack of common low-ionization features (Mg II, Fe II), we argue these arise from the same absorbing material responsible for the low-velocity outflow discovered at X-ray wavelengths. The broad nuclear emission lines display a remarkable abundance pattern: N III], N IV], and He II are quite prominent, while the common quasar emission lines of C III] and Mg II are weak or entirely absent. Detailed modeling of this spectrum will help elucidate fundamental questions regarding the nature of the emission processes at work in TDFs, while future UV spectroscopy of ASASSN-14li would help to confirm (or refute) the previously proposed connection between TDFs and "N-rich" quasars.

Author(s): Stephen B. Cenko[1]
Institution(s): *1. NASA Goddard Space Flight Center*

300.04 – The Compton-thick Growth of Supermassive Black Holes constrained

A heavily obscured growth phase of supermassive black holes (SMBH) is thought to be important in the co-evolution with galaxies. X-rays provide a clean and efficient selection of unobscured and obscured AGN. Recent work with deeper observations and improved analysis methodology allowed us to extend constraints to Compton-thick number densities. We present the first luminosity function of Compton-thick AGN at z=0.5-4 and constrain the overall mass density locked into black holes over cosmic time, a fundamental constraint for cosmological simulations. Recent studies including ours find that the obscuration is redshift and luminosity-dependent in a complex way, which rules out entire sets of obscurer models. A new paradigm, the radiation-lifted torus model, is proposed, in which the obscurer is Eddington-rate dependent and accretion creates and displaces torus clouds. We place observational limits on the behaviour of this mechanism.

Author(s): Johannes Buchner[1], Antonis Georgakakis[1], Kirpal Nandra[1], Murray Brightman[1], Marie-Luise Menzel[1], Zhu Liu[1], Li-Ting Hsu[1], Mara Salvato[1], Cyprian Rangel[1],James Aird[1]
Institution(s): *1. MPE*

300.05 – Studying microquasars with IXPE

While timing and spectroscopy of microquasars are well established techniques, X-ray polarimetry is lagging behind, despite its widely recognized importance in providing vital information on the phsyics and geometry of these sources, including strong gravity effects. Happily, this will change very soon thanks to the approval by NASA of IXPE (the Imaging X-ray Polarimetry Explorer), the next mission inthe SMEX program, to be launched in 2020.

In this contribution, the main scientific results expected by IXPE on microquasars will be discussed, with particular emphasys on the possibility to measure the black hole spin via energy-dependent polarization observations.

Author(s): Giorgio Matt[1]
Institution(s): *1. University Roma Tre*

300.06 – V404 Cyg with NuSTAR: relativistic reflection, jets and spin

In summer 2015 the Galactic LMXB V404 Cyg, one of the closest known black hole binary systems, went through its first major outburst in ~25 years, triggering a massive multiwavelength monitoring campaign to cover this remarkable event. In this talk, I will discuss results from the NuSTAR contribution to this campaign, focusing in particular on the data obtained during the height of the outburst activity. These data reveal a variety of extreme behaviour, from intense ~Eddington level flares to strong relativistic reflection. The contemporaneous onset of radio emission strongly suggests that this X-ray flaring is related to jet activity, with the ejected plasma/ base of the jet becoming the source of illumination of the disc. We are able to use the reflection observed to place constraints on the system geometry during these events, finding that the X-ray emitting regions in the jet are located very close to the black hole. In addition, our reflection analysis also allows us to place the first constraints on the black hole spin, and we find that V404 Cyg likely hosts a rapidly rotating black hole.

Author(s): Dom Walton[1], Kunal Mooley[2]
Institution(s): *1. University of Cambridge, 2. University of Oxford*

301 – The Future of Spectral-Timing of Compact Objects

301.01 – Observations of X-ray reverberation around accreting black holes

Accreting black hole (BH) systems show strong, aperiodic variability over a wide range of time scales. The variable X-ray radiation interacts with any surrounding matter, including the accretion disc. Short time delays are expected between primary X-rays and reprocessed emission in the disc. These "X-ray reverberation lags" map the relative distance between the X-ray source and the accretion disc, therefore they are a powerful tool to map the geometry of the inner regions of the accretion flow. I will review observations of X-ray reverberation lags in accreting BH systems, discussing the analogies between X-ray reverberation lags in active galactic nuclei (AGN) and in BH X-ray binaries (BHXRB), and showing how the latter provide evidence of evolving disc geometry during the outburst.

Author(s): Barbara De Marco[1]
Institution(s): *1. N. Copernicus Astronomical Center of the Polish Academy of Sciences*

301.02 – Reverberation modeling with General Relativistic Ray Tracing Simulations

Over the last few years the study of X-ray reverberation - echoes of hard X-rays reflecting off the inner accretion disk - has matured significantly. Approximately half of the variable Seyferts in the XMM-Newton archive show signatures of reverberation in the iron K line, where variations in iron K photons lag behind variations in the power-law continuum. I will introduce the basic concepts and framework for modeling these reverberation lags using general relativistic ray tracing simulations. In order to build up some intuition, I will discuss the time-resolved response of an accretion disk in the simplest lamppost model, where a point-source of X-ray irradiates the disk. Moreover, I will discuss the dependence of the lags on parameters such as the height of the X-ray source, black hole mass, spin and inclination.

Author(s): Edward Cackett[1]
Institution(s): *1. Wayne State University*

301.03 – Beyond the lamppost: Probing the structure and evolution of the extended corona with X-ray reverberation

One of the greatest breakthroughs in recent years has been the discovery of X-ray reverberation off the accretion discs around supermassive black holes. Time delays between variations in the continuum emission and its reflection from the disc are short showing that X-ray reverberation is probing the innermost structure of the accretion disc and the extreme environment in the immediate vicinity of the event horizon.

Measurements of X-ray reverberation are revealing a wealth of information and present a number of inconsistencies with simple models of X-ray emission originating from the point source or 'lamppost' that has often been assumed. To self-consistently describe the full suite of observations, it is necessary to consider the propagation of variability through extended coronae.

X-ray reverberation measurements are opening a new window to probe the inner regions of the accretion flow and the physics of the mysterious, albeit important corona. Interpreting observations in the light of reverberation models derived from general relativistic ray tracing simulations reveals not just the location and geometry of the corona but points toward distinct structures within the corona and their evolution, including a collimated core, hinting at the connection between the accretion disc, the corona and a jet.

Understanding not just the structure of the corona but how it evolves over time places important constraints on the mechanisms by which energy is liberated from the material accreting onto black holes, powering some of the most luminous objects we see in the Universe.

Author(s): Dan Wilkins[1]
Institution(s): *1. Stanford University*

301.04 – Stingray: Open-source spectral-timing software

New ideas about how to analyze 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 merges existing efforts for a timing package in Python and provides the basis for developing *spectral*-timing analysis tools, while following the Astropy guidelines for modern open-source scientific programming. Stingray has a scripting interface, an affiliated graphical user interface, and a well-documented application programming interface (API) for power-users. The ultimate 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 new data from NICER and potentially STROBE-X. Stingray is pip-installable via the Python Package Index, and we welcome community involvement on our GitHub code repository. For more information, see the Stingray website: http://stingraysoftware.github.io/

Author(s): Abigail L Stevens[5], Matteo Bachetti[3], Paul Balm[4], Daniela Huppenkothen[1], Simone Migliari[2]
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302 – Synergies with the Millihertz Gravitational Wave Universe

302.01 – The growth of supermassive black holes in cosmological simulations

Supermassive black holes (SMBHs) can grow via the accretion of gas and by mergers with other black holes, but which process dominates (and when!) is still very uncertain. While future missions such as eLISA will help answer these questions, in the meantime cosmological simulations are a vital tool for predicting SMBH populations and merger events. This talk will focus on results from new hydrodynamic, fully cosmological simulations of galaxy formation which include both SMBH mergers and growth by accretion. I will discuss both forms of SMBH growth and address in which mass and redshift regimes each mechanism is dominant, as well as the resulting electromagnetic and gravitational wave signatures.

Author(s): Jillian M. Bellovary[1]
Institution(s): *1. CUNY - Queensborough Community College*

302.02 – Ultracompact Binaries and LISA

I will review the formation and evolution of binary stars with two compact objects. In particular, I will discuss what we already know about this class of objects from electromagnetic observations; evolutionary scenarioes for producing these objects, both from standard binary evolution and dynamically in globular clusters; and what LISA observations might be expected to show and what they might be expected to constrain.

Author(s): Thomas J. Maccarone[1]
Institution(s): *1. Texas Tech University*

302.03 – Observational evidence for supermassive black hole binaries

Gravitationally bound supermassive black hole binaries are thought to be a natural product of galactic mergers and growth of the large scale structure in the universe. They however remain observationally elusive, thus raising a question about characteristic observational signatures associated with these systems. In my talk I will discuss current theoretical understanding and latest advances made in observational searches for supermassive black hole binaries.

Author(s): Tamara Bogdanovic[1]
Institution(s): *1. Georgia Institute of Technology*

303 – Dissertation Prize Talk - Stellar Death by Black Hole: How Tidal Disruption Events Unveil the High Energy Universe, Eric Coughlin

303.01 – Stellar Death by Black Hole: How Tidal Disruption Events Unveil the High Energy Universe

When a star comes very close to a supermassive black hole, the tidal field of the hole can be strong enough to deform and stretch the star into a stream of debris. Half of this stellar debris stream returns to the black hole and forms an accretion disk, briefly lighting up the black hole and, in the most extreme cases, launching relativistic jets. These ``tidal disruption events,'' from the initial stellar destruction to the eventual jet production, are the focus of my thesis, and during this talk I will describe some of the theoretical advances we have made in understanding them. I will also discuss more recent work that shows how this relatively simple picture can be more complicated when the disrupting black hole is part of a binary system. Despite the added complexity, I will argue that there is a timescale over which one expects to see variation in the luminosity of a tidal disruption event from a binary supermassive black hole system. Using these predictions and a set of simulations, I will motivate such an interpretation for the superluminous supernova ASASSN-15lh.

Author(s): Eric Robert Coughlin[1]
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304 – Missions & Instruments

304.01 – CIAO: A Modern Data Analysis System for X-Ray Astronomy

It is now eighteen years after launch and Chandra continues to produce spectacular results!
A portion of the success is to be attributed to the data analysis software CIAO (Chandra Interactive Analysis of Observations) that the Chandra X-Ray Center (CXC) continues to improve and release year after year.
CIAO is downloaded more than 1200 times a year and it is used by a wide variety of users around the world: from novice to experienced X-ray astronomers, high school, undergraduate and graduate students, archival users (many new to X-ray or Chandra data), users with extensive resources and others from smaller countries and institutions.
The scientific goals and kinds of datasets and analysis cover a wide range: observations spanning from days to years, different instrument configurations and different kinds of targets, from pointlike stars and quasars, to fuzzy galaxies and clusters, to moving solar objects. These different needs and goals require a variety of specialized software and careful and detailed documentation which is what the CIAO software provides. In general, we strive to build a software system which is easy for beginners, yet powerful for advanced users.
The complexity of the Chandra data require a flexible data analysis system which provides an environment where the users can apply our tools, but can also explore and construct their own applications. The main purpose of this talk is to present CIAO as a modern data analysis system for X-ray data analysis.
CIAO has grown tremendously over the years and we will highlight (a) the most recent advancements with a particular emphasis on the newly developed high-level scripts which simplify the analysis steps for the most common cases making CIAO more accessible to all users - including beginners and users who are not X-ray astronomy specialists, (b) the python-based Sherpa modelling and fitting application and the new stand-alone version openly developed and distributed on Github and (c) progress on methods to characterize the Chandra PSF.

Author(s): Antonella Fruscione[1]
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304.02 – 360-degree video and X-ray modeling of the Galactic center's inner parsec

360-degree videos, which render an image over all 4pi steradian, provide a unique and immersive way to visualize astrophysical simulations. Video sharing sites such as YouTube allow these videos to be shared with the masses; they can be viewed in their 360° nature on computer screens, with smartphones, or, best of all, in virtual-reality (VR) goggles. We present the first such 360° video of an astrophysical simulation: a hydrodynamics calculation of the Wolf-Rayet stars and their ejected winds in the inner parsec of the Galactic center. Viewed from the perspective of the super-massive black hole (SMBH), the most striking aspect of the video, which renders column density, is the inspiraling and stretching of clumps of WR-wind material as they makes their way towards the SMBH. We will brielfy describe how to make 360° videos and how to publish them online in their desired 360° format.

Additionally we discuss computing the thermal X-ray emission from a suite of Galactic-center hydrodynamic simulations that have various SMBH feedback mechanisms, which are compared to Chandra X-ray Visionary Program observations of the region. Over a 2-5" ring centered on Sgr A*, the spectral shape is well matched, indicating that the WR winds are the dominant source of the thermal X-ray emission. Furthermore, the X-ray flux depends on the SMBH feedback due to the feedback's ability to clear out material from the central parsec. A moderate outburst is necessary to explain the current thermal X-ray flux, even though the outburst ended ~100 yr ago.

Author(s): Christopher Michael Post Russell[1], Daniel Wang[3], Jorge Cuadra[2]
Institution(s): *1. NASA/GSFC, 2. Pontificia Universidad Católica de Chile, 3. University of Massachusetts Amherst*

304.03 – Spectral analysis of the Crab Nebula and GRB 160530A with the Compton Spectrometer and Imager

The Compton Spectrometer and Imager (COSI) is a balloon-borne soft gamma-ray (0.2-5 MeV) telescope designed to study astrophysical sources including gamma-ray bursts and compact objects. As a compact Compton telescope, COSI has inherent sensitivity to polarization. COSI utilizes 12 germanium detectors to provide excellent spectral resolution. On May 17, 2016, COSI was launched from Wanaka, New Zealand and completed a successful 46-day flight on NASA's new Superpressure balloon. To perform spectral analysis with COSI, we have developed an accurate instrument model as required for the response matrix. With carefully chosen background regions, we are able to fit the background-subtracted spectra in XSPEC. We have developed a model of the atmosphere above COSI based on the NRLMSISE-00 Atmosphere Model to include in our spectral fits. The Crab and GRB 160530A are among the sources detected during the 2016 flight. We present spectral analysis of these two point sources. Our GRB 160530A results are consistent with those from other instruments, confirming COSI's spectral abilities. Furthermore, we discuss prospects for measuring the Crab polarization with COSI.

Author(s): Clio Sleator[5], Steven E. Boggs[6], Jeng-Lun Chiu[5], Carolyn Kierans[5], Alexander Lowell[5], John Tomsick[5], Andreas Zoglauer[5], Mark Amman[4], Hsiang-Kuang Chang[1],Chao-Hsiung Tseng[1], Chien-Ying Yang[1], Chih H Lin[2], Pierre Jean[3], Peter von Ballmoos[3]
Institution(s): *1. Institute of Astronomy, National Tsing-Hua University, 2. Institute of Physics, Academia Sinica, 3. IRAP Toulouse, 4. Lawrence Berkeley National Laboratory, 5. Space Sciences Laboratory, UC Berkeley, 6. University of California, San Diego*

304.04 – LISA Pathfinder: An important first step towards a space-based gravitational wave observatory

ESA's LISA Pathfinder mission was launched on Dec 3rd, 2015 and completed earlier this Summer. During this relatively short mission, Pathfinder at its two science payloads, Europe's LISA Technology Package and NASA's Disturbance Reduction System, demonstrated several techniques and technologies that enable development of a future space-based gravitational wave observatory. Most notably, Pathfinder demonstrated that the technique of drag-free flight could be utilized to place a test mass in near-perfect free-fall, with residual accelerations at the femto-g level in the milliHertz band. Additionally, technologies such as precision bonded optical structures for metrology, micropropulsion systems, and non-contact charge control, were successfully tested, retiring risk for LISA. In this talk, I will present an overview of Pathfinder's results to date and some perspective on how this success will be leveraged into realizing LISA.

Author(s): James Thorpe[1]
Institution(s): *1. NASA GSFC*

304.05 – Arcus: Exploring the formation and evolution of clusters, galaxies, and stars

Arcus, a proposed soft X-ray grating spectrometer Explorer, leverages recent advances in critical-angle transmission (CAT) gratings and silicon pore optics (SPOs), using CCDs with strong Suzaku heritage and electronics based on the Swift mission; both the spacecraft and mission operations reuse highly successful designs. To be launched in 2023, Arcus will be the only observatory capable of studying, in detail, the hot galactic and intergalactic gas that is the dominant baryonic component of the present-day Universe and ultimate reservoir of entropy, metals and the output from cosmic feedback. Its superior soft (12-50Å) X-ray sensitivity will complement forthcoming calorimeters, which will have comparably high spectral resolution above 2 keV.

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

304.06 – The cosmic monster quest: hunting MeV blazars with AMEGO

The All-Sky Medium Energy Gamma-ray Observatory (AMEGO) will explore the energy regime from 200 keV and 10 GeV with unprecedented sensitivity. Its wide field of view will allow us to observe the entire sky every three hours, making AMEGO a prime mission to study the long-term and short-term behavior of Active Galactic Nuclei (AGN) in the MeV band. This relatively unexplored energy range is particularly important since it enables us to investigate the emission mechanisms and environments of the MeV blazars, i.e. AGN whose peak power output lies in the MeV range. These distant MeV blazars host monster black holes, i.e., >1 billion solar mass, and are some of the most luminous and most distant gamma-ray AGN. Beside helping us in studying the evolution of supermassive black holes in the early Universe, MeV blazars play a key role in the context of extragalactic gamma ray background studies, especially in the challenging MeV regime.

Author(s): Sara Buson[2], Marco Ajello[1], Vaidehi Sharan Paliya[1], Dieter Hartmann[1], Tonia M. Venters[2]
Institution(s): *1. Clemson University, 2. NASA/GSFC*

305 – SNR/GRB/Gravitational Waves

305.01 – Radiation Transport in Dynamic Spacetimes

We present early results from a new radiation transport calculation of gas accretion onto merging binary black holes. We use the Monte Carlo radiation transport code Pandurata, now generalized for application to dynamic spacetimes. The time variability of the metric requires careful numerical techniques for solving the geodesic equation, particularly with tabulated spacetime data from numerical relativity codes. Using a new series of general relativistic magneto-hydrodynamical simulations of magnetized flow onto binary black holes, we investigate the possibility for detecting and identifying unique electromagnetic counterparts to gravitational wave events.

Author(s): Jeremy Schnittman[1], John G. Baker[1], Zachariah Etienne[3], Bruno Giacomazzo[2], Bernard J. Kelly[1]
Institution(s): *1. NASA/GSFC, 2. Univ Trento, 3. West Virginia University*

305.02 – Exciting (and detecting) gravitational waves from the tidally produced f-modes in highly eccentric neutron star binaries

After the first recent detections of gravitational waves from binary black holes, we expect to observe next gravitational radiation from neutron stars in the near future. Most interestingly, the signal from neutron star binaries could also carry information about the equation of state of cold, catalyzed, dense matter in the interior of neutron stars, which is in a regime not accessible to nuclear and particle physics experiments on Earth. For analyzing this information, more advanced gravitational wave detectors will be needed, such as third-generation detectors like the Einstein Telescope or the Cosmic Explorer. Besides the gravitational wave signal produced by the orbital motion and merger of the binary, a rich spectrum of characteristic fluid oscillations is expected to be produced with low amplitude in the ringdown. The frequencies and physical properties of these modes have been extensively studied in linear perturbation theory (both Newtonian and relativistic) and they have already been found in numerical relativity simulations of isolated neutron stars and of hypermassive remnants of double neutron star mergers. Due to the high frequency of the fundamental (f-)modes, of the order of 1-2 kHz, the resonant excitation of these modes is not expected to be detectable in circular binaries. However, highly eccentric binaries could have the potential for exciting f-modes in their close passages, and recent numerical relativity simulations indicate that the energy deposited in the f-modes could be up to two orders of magnitude greater than predicted in the linear theory. The merger of highly eccentric neutron star binaries will be rare events, but we estimate that up to several tens could be detected per year out to the redshifts ~2-6 accessible with third-generation instruments. Finally, we note that the information from the amplitude, frequency and damping time of the f-modes can be used for simultaneously measuring the masses, moments of inertia and tidal Love numbers of the stars, providing an opportunity to test the I-Love-Q relation observationally.

Author(s): Cecilia Chirenti[2], Roman Gold[1], M. Coleman Miller[3]
Institution(s): *1. Perimeter Institute, 2. UFABC, 3. University of Maryland*

305.03 – X-ray observations of the Crushed Pulsar Wind Nebula and Rapidly Moving Pulsar in SNR MSH 15-56

Composite supernova remnants (SNRs) are those consisting of both a central pulsar that produces a wind of synchrotron-emitting relativistic particle and a supernova (SN) blast wave that expands into the surrounding interstellar medium (ISM). The evolution of the pulsar wind nebula (PWN) is coupled to the evolution of its host SNR and characterized by distinct stages, from the PWN's early expansion into the unshocked SN ejecta to its late-phase interaction with the SNR reverse shock. The signatures of this PWN/SNR interaction can reveal important information about the SNR and PWN dynamics, the ambient medium, particle injection and loss processes, and the eventual escape of PWN's energetic particles into the interstellar medium. I will present the analysis of recent X-ray observations of the evolved composite SNR MSH 15-56 that appears to have undergone an asymmetric interaction with the SN reverse shock. Such an asymmetric interaction can occur as a result of a density gradient in the ambient medium and/or a moving pulsar that displaces the PWN from the center of the SNR. The 15-year baseline of the Chandra observations allowed us to measure the proper motion of the pulsar, which indeed shows that it is moving at a high velocity. This analysis provides new insight into the evolution of this complex SNR and the late-phase evolution of composite SNRs in general.

Author(s): Tea Temim[3], Patrick O. Slane[1], Paul P. Plucinsky[1], Daniel Castro[1], Joseph Gelfand[2]
Institution(s): *1. Harvard-Smithsonian CfA, 2. New York University Abu Dhabi, 3. Space Telescope Science Institute*

305.04 – The Three-Dimensional Expansion of the Ejecta from Tycho's Supernova Remnant

We present the first three-dimensional measurements of the velocity of various ejecta knots in Tycho's supernova remnant, known to result from a Type Ia explosion. Chandra X-ray observations over a 12-year baseline from 2003 to 2015 allow us to measure the proper motion of nearly 60 ``tufts'' of Si-rich ejecta, giving us the velocity in the plane of the sky. For the line of sight velocity, we use two different methods: a non-equilibrium ionization model fit to the strong Si and S lines in the 1.2-2.8 keV regime, and a fit consisting of a series of Gaussian lines. These methods give consistent results, allowing us to determine the red or blue shift of each of the knots. Assuming a distance of 3.5 kpc, we find total velocities that range from 2400 to 6600 km s^{-1}, with a mean of 4430 km s^{-1}. We find several regions where the ejecta knots have overtaken the forward shock. These regions have proper motions in excess of 6000 km s^{-1}. Some Type Ia supernova explosion models predict a velocity asymmetry in the ejecta. We find no such velocity asymmetries in Tycho, and discuss our findings in light of various explosion models, favoring those delayed detonation models with relatively vigorous and symmetrical deflagrations. Finally, we compare measurements with models of the remnant's evolution that include both smooth and clumpy ejecta profiles, finding that both ejecta profiles can be accommodated by the observations.

Author(s): Brian J. Williams[3], Nina Coyle[5], Hiroya Yamaguchi[1], Joseph M. DePasquale[3], Ivo Rolf Seitenzahl[6], John W. Hewitt[7], John M. Blondin[2], Kazimierz J. Borkowski[2],Parviz Ghavamian[4], Robert Petre[1], Stephen P. Reynolds[2]
Institution(s): *1. NASA Goddard, 2. North Carolina State University , 3. Space Telescope Science Institute, 4. Towson University, 5. University of Chicago, 6. University of New South Wales, 7. University of North Florida*

305.05 – Significant and variable polarization during the bright prompt optical flash of GRB 160625B

Measurements of polarized light provide a direct probe of magnetic fields and emission mechanisms in GRB outflows, and can potentially address key open questions in GRB physics. However, due to the unpredictable and short-lived nature of these transients, polarimetric observations during the prompt GRB phase are rare and often inconclusive. In this contribution we report the detection of linear polarization during the bright prompt optical emission of GRB 160625B. Our measurements probe the structure of the magnetic field at an early stage of the GRB jet, and suggest that GRB outflows might be launched as Poynting flux dominated jets whose magnetic energy is rapidly dissipated close to the source, after which they propagate as hot baryonic jets with a relic magnetic field. Finally, we discuss the implications of our results for the production of ultra high-energy cosmic-rays in GRB jets.

Author(s): Eleonora Troja[1]
Institution(s): *1. University of Maryland*

305.06 – Time Domain Astronomy with Fermi GBM in the Multi-messenger Era

As the Multi-Messenger era begins with detections of gravitational waves with LIGO and neutrinos with IceCube, the Fermi Gamma-ray Burst Monitor provides context observations of gamma-ray transients between 8 keV and 40 MeV. Fermi GBM has a wide field of view, high uptime, and both in-orbit triggering and high time resolution continuous data enabling offline searches for weaker transients. GBM detects numerous gamma-ray bursts (GRBs), soft gamma-ray repeaters, X-ray bursters, solar flares and terrestrial gamma-ray flashes. Longer timescale transients, predominantly in our galaxy so far, are detected using the Earth occultation technique and epoch-folding for periodic sources. The GBM team has developed two ground-based searches to enhance detections of faint transients, especially short GRBs. The targeted search uses the time and location of an event detected with another instrument to coherently search the GBM data, increasing the sensitivity to a transient. The untargeted search agnostically searches the GBM data for all directions and times to find weaker transients. This search finds about 80 short GRBs per year, in addition to the 40 per year triggered on-orbit. With its large field of view, high duty cycle and increasingly sophisticated detection methods, Fermi GBM is expected to have a major role in the Multi-Messenger era.

Author(s): Colleen A. Wilson-Hodge[1]
Institution(s): *1. NASA/MSFC*

306 – Cosmic Ray Feedback: From Supernova Remnants to Galaxy Clusters

306.01 – The Basis for Cosmic Ray Feedback

Cosmic rays are a promising agent of star formation and black hole feedback, but they are not equally effective everywhere. I will discuss the coupling of cosmic rays and thermal gas in a multiphase medium, discuss similarities and differences between cosmic rays and other components of feedback, and describe some of the most pressing challenges in this field.

Author(s): Ellen Gould Zweibel[1]
Institution(s): *1. Univ. of Wisconsin*

306.02 – The Microphysics of Cosmic-ray Feedback in Supernova Remnants and Beyond

When the bulk speed of cosmic rays (CR) exceeds the Alfv\'en velocity of the background plasma, Alfv\'en waves become unstable to CR streaming instabilities. These instabilities amplify background magnetic fields and scatter the CRs, which are the key microphysical processes that control the acceleration and propagation of CRs, and mediate CR feedback to the background gas. I will describe numerical methods that follow the linear to non-linear evolution of these instabilities, focusing on a novel magnetohydrodynamic (MHD)-particle-in-cell (PIC) approach, which captures the full kinetic nature of the CRs at substantially reduced computational cost compared to conventional PIC methods. I will discuss CR acceleration in supernova remnant shocks, where the non-resonant (Bell) streaming instability primarily mediates the upstream turbulence to provide the source of scattering in the Fermi process. I will then discuss preliminary studies of the resonant streaming instability, which is the basis for the theory of CR self-confinement and CR-driven wind.

Author(s): Xue-Ning Bai[1]
Institution(s): *1. Institute for Advanced Study, Tsinghua University*

306.03 – The Spatially Uniform Spectrum of the Fermi Bubbles: the Leptonic AGN Jet Scenario

The Fermi bubbles, two giant gamma-ray bubbles above and below the Galactic center (GC), are one of the most important findings of the Fermi gamma-ray space telescope. Because of the proximity, spatially resolved, multi-wavelength observations offer excellent opportunities to learn about the physical origin of the bubbles as well as cosmic-ray (CR) transport, Galactic magnetic fields, and past activity of the GC. One of the unique signatures of the observed bubbles is that their gamma-ray spectrum, including a high-energy cutoff at ~150 GeV and the overall shape of the spectrum, is nearly spatially uniform. The high-energy spectral cutoff is suggestive of a leptonic origin as it could be a signature of synchrotron and inverse-Compton (IC) cooling of CR electrons; however, even for a leptonic model, it is not obvious why the spectrum should be spatially uniform. In this talk, I will introduce a newly implemented CRSPEC module in FLASH that allows us to track the evolution of CR spectrum on-the-fly during the simulations. I will present our simulations of the formation of the Fermi bubble by past AGN jet activity using the CRSPEC code. I will show that the high-energy cutoff is a signature of fast synchrotron and IC cooling near the GC when the jets were first launched. After the jets propagate away from the GC, the dynamical timescale of the jets become the shortest among all relevant timescales, and therefore the spectrum is essentially advected with only mild cooling losses. This could explain why the bubble spectrum is spatially uniform because the CRs from different parts of the bubbles as seen today all share the same origin near the GC at early stage of the bubble expansion.

Author(s): Hsiang-Yi Karen Yang[1], Mateusz Ruszkowski[2], Ellen Gould Zweibel[3]
Institution(s): *1. University of Maryland, 2. University of Michigan, 3. University of Wisconsin-Madison*

306.04 – Modelling stellar feedback and effects of cosmic rays in galaxy formation modelling

I will present recent results in modelling stellar feedback in galaxy formation simulations, including explorations of effects cosmic rays injected by supernovae could have on the effects of feedback.

Author(s): Andrey Kravtsov[1]
Institution(s): *1. Univ. of Chicago*

306.05 – Cosmic Ray Feedback Heating of the Intracluster Medium

Self-regulating active galactic nuclei (AGN) feedback in the cool cores of galaxy clusters plays central role in solving the decades-old cooling flow problem. While there is consensus that AGN provide most if not all of the energy needed to offset radiative losses in the intracluster medium (ICM) and prevent catastrophically large star formation rates, one major problem remains – how is the AGN energy thermalized in the ICM and what are the effective black hole feeding rates in realistic systems? We perform a suite of 3D magneto-hydrodynamical (MHD) adaptive mesh refinement simulations of AGN feedback in a cool core cluster including cosmic ray (CR) physics. CRs are supplied to the ICM via collimated AGN jets and subsequently disperse in the magnetized ICM via streaming, and interact with the ICM via hadronic, Coulomb, and streaming instability heating. We find that CR transport is an essential model ingredient at least within the context of the physical model considered here. When CR streaming is included, CRs come into contact with the ambient ICM and efficiently heat it. Moreover, the dynamical state and intermittency of the central AGN are dramatically altered when CR streaming is present – while the AGN is never in a completely off-state, it is more variable, and the atmosphere goes through cycles characterized by low gas velocity dispersion interspersed with more violent episodes. We find that CR streaming heating dominates over the heating due to Coulomb and hadronic processes. Importantly, in simulations that include CR streaming, CR pressure support in the central 100 kpc is very low and does not demonstrably violate observational constraints. On the contrary, when CR streaming is neglected, CR energy is not efficiently spent on the ICM heating and CR pressure builds up to a significant level creating tension with the observations. Overall, our models demonstrate that CR heating is a viable channel for the thermalization of AGN energy in clusters, and likely also in elliptical galaxies, and that CRs play an important role in determining AGN intermittency and the dynamical state of cool core atmospheres.

Author(s): Mateusz Ruszkowski[2], Hsiang-Yi Karen Yang[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland, 2. University of Michigan*

307 – Diagnosing Astrophysics of Collisional Plasmas - A Joint HEAD/LAD Session

307.01 – Observations of Collisional Plasmas with Hitomi: Results and Open Questions

I will review the Hitomi observations of collisional plasmas, and describe successes and challenges based on the state-of-the-art plasma modeling. The unprecedented spectral resolution of the Hitomi/SXS enabled accurate determination of the turbulent velocities and metal abundances of the intra-cluster medium in the Perseus Cluster, which radically altered our understanding of the dynamics and chemical enrichment in this object. At the same time, the high-resolution X-ray data led to significant improvement in the atomic models, such as AtomDB and SPEX -- I will briefly overview how this improvement was made. Nevertheless, there are still significant discrepancies among the public atomic models, causing systematic uncertainties in measurements of the temperature, abundance, and degree of the resonance scattering. Requirements for future improvements will be summarized in this context. I will also present the SXS observation of the supernova remnant N132D. Even though the exposure was short, the SXS detected several emission features and successfully constrained the Doppler velocity of each element. I will describe how this measurement relied on the underlying atomic data. Finally, it should be noted that, because of the short life of the mission with the SXS aperture door closed, we were not able to obtain any L-shell spectra or K-shell fluorescence data from non-equilibrium plasma. Studies of these emission from celestial sources are left for future X-ray observatories.

Author(s): Hiroya Yamaguchi[1]
Institution(s): *1. NASA/GSFC*

307.02 – The Livermore EBIT laboratory astrophysics program in a new era of atomic physics data needs

Recently, observations with the Hitomi microcalorimeter Soft X-ray Spectrometer (SXS) have highlighted open issues of currently available plasma models and their underlying atomic physics databases. In preparation for future X-ray micro calorimeter missions, such as XARM or Athena, improvements to these models and databases play an integral role in ensuring our ability to take full advantage of the diagnostic power that spectra from these missions have been shown to deliver. Benchmark and reference atomic data measured in a well understood, controlled laboratory environment are essential to reach this goal. The Livermore electron beam ion trap EBIT-I, in conjunction with a suit of high-resolution spectrometers, such as crystal spectrometers and the EBIT Calorimeter Spectrometer (ECS) with similar properties to the SXS, is ideally suited to provide such measurements. In this overview, we will describe how our EBIT measurements provide reference data with accuracies fulfilling current and future requirements on the atomic data. For example, the accuracy for energies of K-shell transitions in L-shell ions of Si and S as measured with the ECS exceeds the calibration accuracy of the Chandra HETG, while measurements with a spherical crystal spectrometer have accuracies corresponding to Doppler shifts smaller than 30km/s, exceeding the requirements set by the Athena observatory. In addition, our measurements of absolute collisional excitation cross sections for K-shell transitions in highly-charged Fe and Fe-group elements currently have accuracies on the ~10% level, in line with pre-Hitomi requirements, with new efforts allowing to push these uncertainties to a few percent.

Work was performed under auspices of U.S. D.o.E. by LLNL under contract DE-AC52-07NA27344 and supported by NASA grants to LLNL and GSFC.

Author(s): Natalie Hell[2], Gregory V. Brown[2], Peter Beiersdorfer[2], Richard L. Kelley[3], Caroline Kilbourne[3], Maurice A. Leutenegger[3], Tom Lockard[2], Frederick Scott Porter[3],Joern Wilms[1]
Institution(s): *1. ECAP, FAU Erlangen-Nürnberg, 2. LLNL, 3. NASA GSFC*

307.03 – Modeling Collisional Plasmas - Theory, Databases, and Codes

Modeling the emissions of hot collisional plasmas requires not only a plasma code, but also a substantial database of atomic levels and reaction rates that can only be completed using theoretical calculations, backed by individual checks of key wavelengths and rates against laboratory measurements. The Hitomi observation of the Perseus cluster have spurred a revolution in plasma modeling, revealing a number of places where current codes and databases such as AtomDB and SPEX needed to be updated. An important lesson learned from Hitomi data analysis is that the uncertainties on the reaction rates, such as collision strength, contributes one of the main errors in the results; even for the simplest hydrogen-like systems, the fractional uncertainties on line fluxes can still reach about 15%. This talk will discuss how these kinds of issues were identified and treated, and speculate on further updates that will be needed as more high-resolution spectral data are obtained.

Author(s): Liyi Gu[1]
Institution(s): *1. RIKEN*

400 – Solar/Stellar Compact II

400.01 – The Swift Bulge Survey - in search of the faintest X-ray transients

Very Faint X-ray Transients (VFXTs) show peak X-ray luminosities in the range 10E(34-36) erg/s. The luminosities of these sources implies 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. We have recently initiated the Swift Bulge Survey (SBS), a wide, shallow Swift/XRT imaging survey of 16 square degrees of the Galactic Bulge, to be performed fortnightly for 15 epochs, with the intention of uncovering ~15 new VFXTs over the course of the survey. Here I report on the results from the first phase of the survey. I will detail the radio, optical/NIR and X-ray follow-up of sources discovered in the SBS, as well as the first multi-band NIR photometry of previously known VFXTs in an attempt to place constraints on their counterparts and investigate the nature of accretion in these systems.

Author(s): Aarran W. Shaw[6], Craig O. Heinke[6], Arash Bahramian[2], Thomas J. Maccarone[5], Jamie A Kennea[3], Erik Kuulkers[1], Nathalie Degenaar[7], Gregory R. Sivakoff[6], Rudy Wijnands[7], Jay Strader[2], Jean in 't Zand[4]
Institution(s): *1. ESA, 2. Michigan State University, 3. Penn State University, 4. SRON, 5. Texas Tech University, 6. University of Alberta, 7. University of Amsterdam*

400.02 – Comparing origins of low-frequency quasi-periodic oscillations with spectral-timing

The light curves of low-mass X-ray binaries show variability on timescales from milliseconds to months. The rapid (sub-second) variability is particularly interesting because it is thought to probe the inner region of the accretion disk and the central compact object. Observations suggest that different types of low-frequency quasi-periodic oscillations (QPOs) are associated with different emitting-region geometries (e.g., disk-like or jet-like) in the innermost part of the X-ray binary, that are varying possibly due to general relativistic precession. A new way to analyze QPOs is with spectral-timing, which seeks to investigate how matter behaves in the strong gravitational field around the compact object by causally linking the variations from different spectral components. We developed a technique for phase-resolved spectroscopy of QPOs, and are applying it to two types of low-frequency QPOs from the black hole X-ray binary GX 339-4. Over a QPO “period”, we find that the energy spectrum changes not only in normalization, but also in spectral shape. We can quantify how the spectral shape changes as a function of QPO phase, and the two different

QPOs show markedly different spectral changes. The "Type B" low-frequency QPO shows evidence of a large-scale-height (jet-like) power-law- emitting precessing region, while in the same outburst the "Type C" low-frequency QPO shows evidence of a small-scale-height (disk-like) power-law-emitting precessing region. These interpretations can be used to look into the evolution of matter in the strong-gravity regime.

Author(s): Abigail L Stevens[1], Phil Uttley[1]
Institution(s): *1. University of Amsterdam*

400.03 – The Hard X-ray Variability of the LMC X-1 system

Only two parameters are needed to completely describe the physics of a black hole: its mass and its spin. This is true for both stellar mass black holes as well as for the supermassive black holes that reside in the centers of most galaxies. While these two parameters are fundamental to our understanding of black holes, accurately measuring the spin of a black hole is a challenge in modern astrophysics and many spins of black hole systems are only measurable when the system goes into outburst and the luminosity increases to nearly the Eddington limit from quiescence (~1e-6 Eddington). Persistently accreting systems, in contrast, should instead allow to probe accretion physics in a more steady-state accretion mode. We report on NuSTAR and XMM observations of the persistent wind-fed black hole binary LMC X-1, which is a moderately accreting (10% Eddington) system. Over two NuSTAR epochs and one joint NuSTAR-XMM observations we find significant variation in the hardness and intensity of the source as well as an X-ray flare observed by both XMM and NusTAR. The variability of the source impacts the measurement of the spin of the black hole and the interpretation of the X-ray spectrum. We will discuss our findings, and the implications of these results.

Author(s): Brian Grefenstette[1], Felix Fuerst[2], Jon M. Miller[9], Michael Nowak[5], David M. Smith[7], John Tomsick[6], Dom Walton[8], Joern Wilms[3], Matteo Bachetti[4]
Institution(s): *1. Caltech, 2. ESAC, 3. FAU Erlangen-Nuremberg, 4. INAF-Osservatorio Astronomico di Cagliari, 5. MIT, 6. UCBerkeley - Space Sciences Lab, 7. UCSC, 8. University of Cambridge, 9. University of Michigan*

400.04 – Cygnus X-3 Returns to an Active State

Cygnus X-3 is a well-known microquasar composed of a mass-donating Wolf-Rayet star and a compact object. Recently, Cygnus X-3 has been in a quiescent state for an extended period of time (2011-2016) but returned to an active state on two occasions during 2016/2017 including quenched/hypersoft states, gamma-ray emission, and major radio flares. During these two periods of activity, we undertook multi-wavelength observing campaigns with observations in the radio (RATAN-600, AMI-LA, Metsähovi), submillimeter (SMA, EHT), X-ray (Swift/XRT, MAXI), hard X-ray (Swift/BAT, NuSTAR), and gamma-ray (AGILE, Fermi, VERITAS). At the peak of the major radio flare in April 2017 observations were made with VERITAS (TeV), NuSTAR (hard X-ray), and the Event Horizon Telescope (submillimeter). In this presentation, I will review these observing campaigns and the insights they provide about Cygnus X-3.

Author(s): Michael L. McCollough[2], Karri Koljonen[1], Mark A. Gurwell[2], Sergei Trushkin[4], Guy G Pooley[3]
Institution(s): *1. FINCA, University of Turku, 2. Harvard-Smithsonian, CfA, 3. MRAO, 4. Special Astrophysical Observatory*

400.05 – High-Precision Single Photon Timing of Pulsars

We have developed a likelihood-based technique, implemented through Markov Chain Monte Carlo, that enables high-precision pulsar timing using individual x-rays or gamma-rays. Our current implementaion leverages the new timing software PINT for timing model details and provides several significant advantages over earlier, more traditional, timing techniques. Our method does not require the integration of an average pulse profile from which a "time of arrival" is computed. This is crucial when the photon count rates are too low to produce a good pulse profile on the timescales of other important timing properties of the system (such as an orbital period of a binary pulsar). Arbitrary weights can be applied to each photon to indicate, for instance, the probability that each event might be a background photon. Many other improvements are being developed, such as simultaneously determining the timing solution and a template profile and parallel calculation of the likelihoods. We have successfully applied the technique to a variety of Fermi pulsars and will be using it extensively for timing analyses during the NICER mission.

Author(s): Scott M. Ransom[1], Paul S. Ray[2], Matthew Kerr[2]
Institution(s): *1. NRAO, 2. NRL*

400.06 – MeV Pulsars: Modeling Spectra and Polarization

A sub-population of energetic rotation-powered pulsars show high fluxes of pulsed non-thermal hard X-ray emission. While this ‘MeV pulsar’ population includes some radio-loud pulsars like the Crab and PSR B1509-58, a significant number have no detected radio or GeV emission, a mystery since gamma-ray emission is a common characteristic of pulsars with high spin-down power. Their steeply rising hard X-ray spectral energy distributions (SEDs) suggest peaks at 0.1 – 1 MeV but they have not been detected above 200 keV. Several upcoming and planned telescopes may shed light on the MeV pulsars. The Neutron star Interior Composition ExploreR (NICER) will observe pulsars in the 0.2 – 12 keV band and may discover additional MeV pulsars. The All-Sky Medium-Energy Gamma-Ray Observatory

(AMEGO), in a study phase, can detect emission above 0.2 MeV and polarization in the 0.2 – 10 MeV band. We present a model for the spectrum and polarization of MeV pulsars where the X-ray emission comes from electron-positron pairs radiating in the outer magnetosphere and current sheet. This model predicts that the peak of the SED increases with surface magnetic field strength if the pairs are produced in polar cap cascades. For small inclination angles, viewing at large angles to the rotation axis can miss both the radio pulse and the GeV pulse from particles accelerating near the current sheet. Characterizing the emission and geometry of MeV pulsars can thus provide clues to the source of pairs and acceleration in the magnetosphere.
Author(s): Alice Kust Harding[1], Constantinos Kalapotharakos[1]
Institution(s): *1. NASA's GSFC*

401 – Galaxy Clusters

401.01 – The Evolution of AGN Feedback in Clusters of Galaxies

Clusters of galaxies exhibit some of the most spectacular examples of AGN-driven outflows in the Universe. These mechanical outflows, known as X-ray cavities, provide a unique opportunity to directly measure the work done by an AGN on its surrounding medium. They are therefore extremely important to study for our understanding of AGN feedback processes. We present new results from clusters of galaxies discovered via the South Pole Telescope. Based on over 1 Ms of Chandra X-ray observations, we provide for the first time constraints on the evolution of mechanical and radiative AGN feedback in clusters out to z=1.2, suggesting that AGN feedback has not evolved significantly in clusters for over half of the age of the Universe (8 Gyrs).
Author(s): Julie Hlavacek-Larrondo[1]
Institution(s): *1. Université de Montréal*

401.02 – The outskirts of galaxy clusters: astrophysics and cosmology

Exploring the virialization region of galaxy clusters has recently raised the attention of the scientific community, offering a direct view of structure formation. In this talk, I will present recent results on the physical properties of the intracluster medium in the outer volumes of a sample of 320 clusters ($0.056 < z < 1.24$, $kT>3$ keV) in the Chandra archive, with a total integration time of ~20 Ms. We stacked the emission measure profiles of the clusters to detect a signal out to R_{100}. We then measured the average emission measure, gas density and gas fraction, which scale according to the self-similar model of cluster formation. We observe a steepening of the density profiles beyond R_{500} with slope β~0.68 at R_{500} and β~1 at R_{200} and beyond. By tracking the direction of the cosmic filaments where the clusters are embedded, we report that galaxy clusters deviate from spherical symmetry. We finally used, for the first time, the high level of similarity of the emission measure in the cluster outskirts as cosmology proxy. The cosmological parameters are thus constrained assuming that the emission measure profiles at different redshift are weakly self-similar, that is their shape is universal, explicitly allowing for temperature and redshift dependence of the gas fraction. This cosmological test, in combination with Planck+SNIa data, allows us to put a tight constraint on the dark energy models. For a constant-w model, we have w=-1.010±0.030 and Ω_m=0.311±0.014, while for a time-evolving equation of state of dark energy $w(z)$ we have Ω_m=0.308±0.017, w_o=-0.993±0.046 and w_a=-0.123±0.400 We checked that our method is robust towards different sources of systematics, including background modelling, outlier measurements, selection effects, inhomogeneities of the gas distribution and cosmic filaments. We also provided for the first time constraints on which definition of cluster boundary radius is more tenable, namely based on a fixed overdensity with respect to the critical density of the Universe. Finally, we present gas inhomogeneities measurements of the outskirts of the poor galaxy group NGC2563.
Author(s): Andrea Morandi[1], Ming Sun[1]
Institution(s): *1. The University of Alabama in Huntsville*

401.03 – Suppression of Electron Thermal Conduction in the Intracluster Medium

The Intracluster Medium (ICM) contains high-temperature dilute plasma in which the quantity beta, defined as the ratio of the thermal pressure of the gas to the local magnetic field pressure, is much larger than unity. In addition, the collisional mean free path of particles in the ICM is typically large compared to the magnetic gyro-radius of individual particles. These conditions allow for the growth of robust microinstabilities that can significantly alter the transport of particles and heat along the local magnetic field line. Here we explore such an instability using driven two-dimensional Particle-In-Cell simulations of a magnetized plasma with a temperature gradient imposed at the boundaries. The system is highly unstable and develops large-amplitude magnetic fluctuations that effectively scatter the orbits of electrons crossing the simulation domain, resulting in a collisionless suppression of thermal conduction across the temperature gradient and magnetic field. The results suggest that the spontaneous development of small-scale plasma turbulence in the ICM may play a pivotal role in determining the thermal conductivity of ICM-like plasmas.
Author(s): Gareth Roberg-Clark[1], James Drake[1], M. Swisdak[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland, College Park*

401.04 – Through the X-ray looking glass, and what plasma physics found there

How energy is transported and dissipated is the most fundamental process in the thermalization and evolution of galaxy clusters. At temperatures of 1--10 keV, intracluster medium (ICM) approximates a highly ionized plasma. Contemporary X-ray observations have revealed a wealth of substructures in the ICM, even in relatively relaxed clusters. Of particular interest is the ubiquitous presence of cold fronts, resulting from the shear interface between gaseous regions of different entropies. This configuration inevitably leads to the Kelvin-Helmholtz Instability (KHI), appearing as “horn” or “roll” features in X-ray images. Both viscosity and ordered magnetic field can suppress the growth of KHI. We present results of Chandra, XMM-Newton, and Suzaku observations of Fornax and Virgo. We probe the cluster plasma physics through the gas properties of the sloshing cold fronts, merging cold fronts, AGN bubbles, and gaseous stripped tails in these systems. We found that the ICM ought to be inviscous and we can put an upper limit on the intracluster magnetic field. Our results have also provided insights into the merging history of galaxy clusters, which have been reproduced in tailored simulations.

Author(s): Yuanyuan Su[1], Ralph P. Kraft[1], Paul Nulsen[1], William R. Forman[1], Christine Jones[1], Elke Roediger[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. University of Hull*

401.05 – Utilizing X-ray gas velocity measurements as a new probe of AGN feedback in giant elliptical galaxies

Velocity structure of hot atmospheres of massive early-type galaxies remains a key open question in our understanding of galaxy formation and mechanical AGN feedback. Using a combination of resonant scattering and direct line broadening techniques applied to deep XMM-Newton Reflection Grating Spectrometer observations has allowed us to for the first time measure turbulent velocities in the cores of 13 nearby giant early-type galaxies, opening up the possibility of population studies of hot gas motions in such objects. Our method has also been successfully applied to the Hitomi Perseus observation, serving as an independent velocity probe of the cluster ICM. In this talk I will introduce our measurements and discuss their implications on the physics of kinetic AGN feedback. I will also outline future directions, emphasizing the role of resonant scattering in studying gas dynamics of cooler (~1 keV) systems, such as giant galaxies, as well as its importance for the correct interpretation of high resolution X-ray spectra from XARM and Athena.

Author(s): Anna Ogorzalek[4], Irina Zhuravleva[4], Steven W. Allen[4], Ciro Pinto[1], Norbert Werner[2], Adam Mantz[4], Rebecca Canning[4], Andrew C Fabian[1], Jelle S. Kaastra[3], Jelle de Plaa[3]
Institution(s): *1. Institute of Astronomy, 2. MTA-Eotvos University, 3. SRON Netherlands Institute for Space Research, 4. Stanford University*

401.06 – The 7 Ms Chandra Deep Field-South Survey: Cosmic Black-Hole Growth is Mainly Linked to Host-Galaxy Stellar Mass

The Chandra exposure on the Chandra Deep Field-South (CDF-S) has recently been increased to 7 Ms, allowing unmatched X-ray and multiwavelength characterization of cosmic black-hole growth in active galactic nuclei (AGNs). We have used these data to investigate the dependence of black-hole accretion rate (BHAR) on host-galaxy star formation rate (SFR) and stellar mass (M_*) at z = 0.5-2. Our sample consists of 18,000 galaxies with SFR and M_* measurements, and we use sample-mean BHAR for these galaxies to approximate their long-term average BHAR. Our sample-mean BHARs are derived from the CDF-S observations via both direct spectral analysis and stacking. The average BHAR is correlated positively with both SFR and M_*, and the BHAR-SFR and BHAR-M_* relations can both be described acceptably by linear models with a slope of unity. However, according to partial-correlation analyses, BHAR is correlated more strongly with M_* than SFR. This result indicates that M_* is the primary host-galaxy property related to black-hole growth, and the well-known BHAR-SFR relation is largely a secondary effect due to the "star-forming main sequence". Among our sources, massive galaxies have significantly higher BHAR/SFR ratios than less-massive galaxies, indicating the former have higher black-hole fueling efficiency and/or higher SMBH occupation fraction than the latter; e.g., the deeper potential wells in higher mass galaxies may promote black-hole accretion and counteract AGN/supernova feedback. Our results can naturally explain the observed proportionality between $M_{\rm BH}$ and M_* for local giant ellipticals, and suggest their $M_{\rm BH}/M_*$ ratios are higher than those of local star-forming galaxies. Finally, prospects for extending this work will be discussed; e.g., by further investigating the redshift evolution of the primary BHAR-M_* relation and measuring this relation for even higher values of M_*, above ~ 10^{11} solar masses, using wide-field X-ray surveys.

Author(s): W. Niel Brandt[1], Guang Yang[1], Chien-Ting Chen[1], Fabio Vito[1]
Institution(s): *1. Penn State Univ.*

Gamma SIG Meeting

402 – Plenary Talk - The Sun as a Library for High-Energy Astrophysics, David Smith

402.01 – The Sun as a Library for High-Energy Astrophysics

Our maternal G dwarf star gives us life, light, warmth, and a surprisingly well-stocked library of high-energy phenomena to study and compare to more distant, violent objects. I will give a survey of what we see from the Sun -- X-rays, gamma-rays, radio emission, energetic neutral atoms, neutrinos, and particles accelerated in the low and high corona -- and of the physical processes and emission mechanisms thought to be involved, including magnetic reconnection, Fermi acceleration, thermal and nonthermal bremsstrahlung, coherent and incoherent radio emission, and gamma-ray line mechanisms: nuclear de-excitation, pion decay, neutron capture, and positron annihilation. I will outline the range of transient coronal behaviors from hypothetical nanoflares below the limit of individual detection to coronal mass ejections and the largest flares, comparing the latter to what is observed from other stars. Throughout the presentation, I will look for parallels with a variety of cosmic objects and observations, with no guarantee that any particular comparison is quantitatively appropriate. Finally, I will advertise the recent contributions of focusing hard X-ray observations with NuSTAR and the FOXSI rockets.

Author(s): David M. Smith[1]
Institution(s): *1. UC, Santa Cruz*

403 – From Stars to Accretion Disks: Why are Coronae So Hot?

403.01 – Radiation Magneto-hydrodynamic simulations of Accretion Disks and Coronae

The formation of coronae in the photosphere of accretion disks is a natural outcome of the accretion process with turbulence generated by magneto-rotational instability. Magnetic fields amplified in the main body of the disks rise up buoyantly and dissipate in the optically thin region, which generates the coronae. Coronae properties and the amount of dissipation that can happen there depend on the detailed structures of the accretion disks. I will summarize the recent efforts to calculate the structures of accretion disks as well as the coronae for a wide range of accretion rates based on first principle radiation magnetohydrodynamic simulations. I will also list the remaining issues that need to be studied in the next few years.

Author(s): Yan-Fei Jiang[1]
Institution(s): *1. University of California, Santa Barbara*

403.02 – Accretion disk observations - An Overview

Accreting systems are amongst the most extreme sources of radiation in the Universe. The energy for this radiation stems from the accretion process. The conversion of gravitational energy into radiation begins in the accretion disk. Yet, despite this important role, our understanding of accretion disks is still poor. In my talk, I will provide an overview of what observations can tell us about accretion disks. I will also discuss problems raised by those observations, such as for example the seemingly larger AGN disks inferred from UV-X-ray lag measurements in some AGN.

Author(s): Anne Lohfink[1]
Institution(s): *1. Montana State University*

403.03 – Investigating coronal heating with focused hard X-ray observations of the Sun

The question of why stellar coronae are much hotter than photospheres is one of the outstanding questions in solar/stellar physics. The large energy required to maintain this temperature difference is thought to arise from mechanical motions in the photosphere, but it is unclear how this energy reaches and is dissipated in the corona. The frequency at which heating occurs provides a clue to understanding the mechanism(s). Impulsive, sporadic energy release, such as that caused by flares, can be distinguished from steady, continuous heating by examining temperature distributions. Impulsive heating would be evidenced in a broad temperature distribution extending to high temperatures (e.g. >10 million degrees for the Sun), while the latter would produce a more narrow temperature spread. A second aspect critical to understanding impulsive coronal heating is the scaling of flare energetic parameters with smaller flare energies. Recent focused hard X-ray studies of the Sun with NuSTAR and the FOXSI rocket are highly sensitive to flare-temperature plasma and reveal solar flares at smaller energies than were available with indirectly imaging hard X-ray instruments. This talk will present observations of these small flares as well as temperature distributions of solar active regions, and will discuss the consequences of these observations for coronal heating.

Author(s): Lindsay Glesener[9], Shin-Nosuke Ishikawa[4], Andrew Marsh[6], Sam Krucker[7], Steven Christe[5], Juan Camilo Buitrago-Casas[7], David M. Smith[6], Iain Hannah[8], Brian Grefenstette[2], Hugh S. Hudson[7], Matej Kuhar[3], Paul Wright[8], Stephen M. White[1], Juliana Vievering[9], Subramania Athiray[9]
Institution(s): *1. AFRL, 2. Caltech, 3. FHNW, 4. JAXA/ISAS, 5. NASA/GSFC, 6. UCSC, 7. University of California, Berkeley, 8. University of Glasgow, 9. University of Minnesota*

403.04 – The Hot Side of Cool M Dwarfs

The study of M dwarfs is experiencing a resurgence of interest, due to their position as hosts to the most Earth-like planets astronomers can find. M dwarfs have always been hot, though: these cool dwarfs have a pervasive outer atmosphere which is capable of maintaining plasma at temperatures only experienced on the Sun during solar flares.

Moreover, their Giga-years long spin-down timescales mean that M dwarfs experience only a slow decline in magnetic activity with age. As part of answering the question posed by the title of this special session, I will investigate two parallel lines of study to explore coronal structures. Studies performed over long timescales constrain quiescent coronal structures in M dwarfs, and can be compared to those predicted/extrapolated from the stellar photosphere. Studies of flaring emission probe smaller timescales of energy release, as well as enable constraints on the structures involved. I'll discuss flares as probes of coronal structures, including their connection to the all-important (but not constrained in the stellar case) coronal mass ejections.

Author(s): Rachel A. Osten[1]
Institution(s): *1. Space Telescope Science Institute*

404 – ULX Pulsars

404.01 – The Physics of Accreting Pulsars

The discovery using NuSTAR that at least three ultraluminous X-ray sources are pulsars has reminded us once again of the diversity of behaviors available to neutron stars. In this presentation, we will present an overview of the basics of accretion onto magnetized neutron stars, including the reduction in scattering opacity for photons with energies significantly less than the electron cyclotron energy. We will also recall some of the theory developed to explain SMC X-1, which has a peak luminosity of ~10^39 erg/s and which could be considered the prototype for ultraluminous pulsars.

Author(s): M. Coleman Miller[1]
Institution(s): *1. Univ. of Maryland*

404.02 – Ultraluminous X-ray Sources in the NuSTAR Era

Ultraluminous X-ray sources are a population of extremely bright extragalactic X-ray binaries that have long caught the imagination. These sources radiate far in excess of the Eddington limit for the standard stellar-remnant X-ray binaries observed in our own Galaxy, and so have traditionally been considered good candidates for the long-postulated and yet seemingly elusive population of 'intermediate mass' black holes. The revelation that some of the most extreme members of the ULX population exhibit X-ray pulsations, and are therefore powered by accreting neutron stars, has therefore brought about a surprising paragidm shift in our understanding of these exotic sources. In light of this recent discovery, I will review our observational understanding of the broader ULX population, with a particular focus on the advances made in the NuSTAR era.

Author(s): Dom Walton[1]
Institution(s): *1. University of Cambridge*

404.03 – Ultraluminous pulsars - current sample, search strategies

Ultraluminous pulsars, a recently discovered subclass of ultraluminous X-ray sources, have challenged the current models of accretion onto magnetized compact objects. Moreover, they might represent a new evolutionary path towards either low-mass black holes and/or millisecond pulsars, as suggested by their very large negative spin derivatives and inferred accretion rates. I will summarize what we have learned so far from the current sample of ultraluminous pulsars, what we might learn from future follow-up observations and surveys, and describe possible future strategies to detect more of these fascinating objects.

Author(s): Matteo Bachetti[1]
Institution(s): *1. INAF-Osservatorio Astronomico di Cagliari*

404.04 – Making Sense of the ULX Pulsars — Theory and Simulation

The ultraluminous X-ray sources emit far in excess of the Eddington limit, implying the presence of geometrically thick, radiation-dominated accretion flows. This regime is very far from the radiatively efficient, cool, thin-disk scenarios for which most of accreting-pulsar theory was developed. I will describe recent theoretical and computational explorations of super-Eddington accretion onto magnetized neutron stars, focusing on what the ULX pulsars' large spin-frequency derivatives may tell us about the strength of their magnetic fields and the overall magnetic geometry in these systems.

Author(s): Kyle Parfrey[1]
Institution(s): *1. Lawrence Berkeley National Laboratory*

405 – AGN II

405.01 – AGN spectral states from simultaneous UV and X-ray observations by XMM-Newton

It is generally believed that the supermassive black holes in active galactic nuclei (AGN) and stellar-mass black holes in X-ray binaries (XRB) work in a similar way. Koerding et al. (2006) suggested that different types of AGN correspond to different spectral states of XRB. In our recent work, we extended their analysis by using data of higher quality - we used the whole XMM-Newton archive to extract a sample of about 1500 sources with high-quality simultaneous UV and X-ray measurements of AGN. The thermal disc component is estimated from the UV flux while the non-thermal flux is constrained from the measured 2-10 keV X-ray luminosity. Our results indicate that sources with the higher fraction of the X-ray flux tend to be radio-loud, have flatter X-ray spectra and UV spectrum inconsistent with the thermal accretion disc emission, as expected from the XRB hard state analogy, and vice versa for the soft states. Our study, therefore, provides an observational support to the hypothesis that accretion onto super-massive black hole work in a similar way as for the stellar-mass black holes in X-ray binaries, and that XRB and AGN follow similar evolutionary paths. This suggests that the AGN radio dichotomy of radio-loud and radio-quiet sources can be explained by the evolution of the accretion states.

Author(s): Jiri Svoboda[1], Matteo Guainazzi[2], Andrea Merloni[3]
Institution(s): *1. Czech Academy of Sciences, 2. European Space Agency, 3. MPE*

405.02 – A hard X-ray view of the hidden AGN population with NuSTAR

New insights into AGNs are being provided by NuSTAR, the first focusing telescope with high sensitivity at hard X-ray energies (E>10 keV), and therefore at the peak energies of the cosmic X-ray background (CXB). I will present results from the 40-month NuSTAR serendipitous survey, which has yielded a large sample of ~500 hard X-ray sources (primarily AGNs), and will compare with results from targeted NuSTAR samples. A crucial part of the AGN census is to identify and characterise the most highly obscured (Compton-thick) AGNs, which may contribute a large fraction of the overall cosmic growth of black holes, but are normally hidden from view by gas and dust. I will show that NuSTAR is identifying new Compton-thick AGNs, which wouldn't have been identified at other wavelengths. These can inform us about the prevalence of such extreme systems in the general AGN population.

Author(s): George Lansbury[4], James Aird[4], David M Alexander[2], Daniel Stern[5], Michael Koss[3], Poshak Gandhi[7], Fiona Harrison[1], John Tomsick[8], Ezequiel Treister[6]
Institution(s): *1. Caltech, 2. Center for Extragalactic Astronomy, Durham University, 3. ETH Zurich, 4. Institute of Astronomy, Cambridge University, 5. JPL / Caltech, 6. Pontificia Universidad Catolica de Chile, 7. Southampton University, 8. UC Berkeley / SSL*

405.03 – Black hole-galaxy co-evolution in the Mufasa simulations

The Mufasa simulations are large-scale cosmological and zoom simulations of galaxy formation that employ novel state of the art modules for star formation and feedback physics, resulting in very good agreement with many key galaxy observables over most of cosmic time. We have recently included black hole growth and feedback using the torque-limited accretion model, which has several advantages over the commonly-used Bondi accretion. We also include AGN feedback using a BAL mode at high Eddington rates and low black hole masses, and a jet mode at low Eddington rates that successfully quenches galaxies. In this talk I will describe preliminary results of the AGN population and its evolution over cosmic time within our new simulations, including cosmological simulations of the general black hole population as well as zoom simulations targeting massive galaxies, with a focus on understanding the co-growth of black holes and galaxies as a function of mass, environment, and cosmic epoch. I will also discuss multi-wavelength approaches to testing and constraining our black hole model in particular using upcoming X-ray and radio facilities such as Lynx and the SKA.

Author(s): Romeel Dave[2], Daniel Angles-Alcazar[1]
Institution(s): *1. Northwestern University, 2. University of Edinburgh*

405.04 – PKS 1718-649: a broad-band study of a young radio jet

Physical conditions required to launch and sustain a jet and the jet's impact on black hole surroundings are believed to be strongly linked, and lie at the core of the AGN feedback idea. The physics of the initial stages of a radio jet expansion is still poorly understood. Nevertheless, highly relativistic plasma contained within young radio lobes and shocks accompanying a powerful jet expansion are expected to generate high energy radiation. However, this initial phase is short-lived and observing young radio sources at high energies has been challenging, with only a few sources detected before the Chandra and XMM-Newton era. We compiled a sample of Compact Symmetric Objects (CSO) that have kinematic age determination to study their high energy properties. Here we discuss one of the sources from our sample, PKS 1718-649 (z=0.014), hosting the most compact (2 pc) and youngest (100 years) extragalactic radio jet known to date. We observed PKS 1718-649 for the first time in X-rays and found that it is a low luminosity X-ray source, L(2-10 keV) ~ 6×10^{41} erg s^{-1}, and its X-ray spectrum is consistent with a mildly (intrinsically) absorbed power law (Gamma ~ 1.75, $N_H \sim 10^{21}$ cm^{-2}). In addition, using the Fermi/LAT archive we established that this source is the first robustly confirmed gamma-ray CSO emitter. Merging the archival radio-to-optical data and our high energy results, we constructed a high quality broad-band spectral energy distribution of this source. We tested a theoretical scenario in which the high energy emission of the source arises due to the Inverse Compton upscattering of the low energy photons off the non-thermal electrons in the expanding radio lobes. We discuss the impact of the expanding lobes on the environment, and constraints imposed by the data on the electron distribution within the lobes.

Author(s): Malgosia Sobolewska[3], Aneta Siemiginowska[3], Giulia Migliori[1], Matteo Guainazzi[2], Martin Hardcastle[6], Luisa Ostorero[5], Lukasz Stawarz[4]

Institution(s): *1. CEA-Saclay, 2. ESTEC/ESA, 3. Harvard-Smithsonian Center for Astrophysics, 4. Jagiellonian University, 5. Universita di Torino, 6. University of Hertfordshire*

405.05 – ALMA Observations of Powerful AGN Jets & the Continuing Mystery of Multi-component Jet Spectra

Over the past several decades, advances in telescope capabilities have enabled the sub-arcsecond-scale studies of resolved jets from Active Galaxies in the radio, optical, and X-rays. The launch of the Chandra X-ray observatory in particular led to the discovery of anomalously X-ray bright quasar jets, which were initially attributed to Inverse Compton upscattering of the CMB (the IC/CMB model). Over the past few years this model has been called into serious question as it has been ruled out in a number of individual cases based on inferred jet speeds, polarization observations, and missing gamma-ray emission, leading to some preference for an alternative, possibly synchrotron, origin for the X-ray component. Against the backdroup of this continuing mystery over the nature of the X-rays, I will discuss extremely surprising discoveries made with ALMA which suggest that our understanding of the emission from AGN jets is far from settled.

Author(s): Eileen T. Meyer[1], Markos Georganopoulos[1], Peter Breiding[1]
Institution(s): *1. University of Maryland, Baltimore County*

405.06 – Thermal and Non-thermal emission in the Jets and Lobes of Cygnus A

We present a spatially-resolved, spectral analysis aimed at detecting and characterizing the non-thermal X-ray emission from the jets and lobes in the powerful radio galaxy Cygnus A based on a new, deep 1 Msec Chandra exposure. These jets and lobes are believed to be a primary means by which energy liberated by accretion onto the central supermassive black hole is transported into the outer galaxy and are integral to understanding the mechanisms that drive AGN feedback. Despite being well-studied over the years, we still do not understand how this energy is transported, the connection between the X-ray and radio structures, and the underlying emission mechanisms that produce them. The X-ray jets in Cygnus A show a clear misalignment with the radio and it has been proposed that they are either inverse Compton-emitting relics or a separate electron population emitting X-ray synchrotron emission. Previous X-ray studies of the jets and lobes have been unsuccessful in distinguishing between these possibilities largely due to the difficulty of separating any non-thermal components from thermal emission in the surrounding hot ICM at CCD spectral resolutions.

In this presentation, we report on a new statistical analysis using MCMC sampling and Bayesian model selection to characterize the X-ray emission in the jets and lobes of Cygnus A. The model includes a mixture of thermal ICM emission and distinct non-thermal components from both the eastern and western jets and lobes. Our analysis clearly favors the presence of non-thermal emission and we find a distinct asymmetry with the western lobe roughly 20% fainter and with a much steeper photon index. Combining existing radio data with our X-ray fluxes and photon indices, we determine the energy densities and pressures for both synchrotron and inverse Compton (IC) emission models. For the IC model, we derive energy densities in the lobes consistent with the external pressure; however, both the eastern and western jets would be over-pressured by almost an order of magnitude arguing strongly for a synchrotron origin. We discuss these results in the context of the evolution of the jets and lobes and their connection to the ongoing feedback process in Cygnus A.

Author(s): Martijn De Vries[4], Michael Wise[1], Daniela Huppenkothen[2], Paul Nulsen[3], Bradford Snios[3], Martin Hardcastle[5]
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