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Meeting Program

Session Table of Contents

100 – AGN I
101 – Galaxy Clusters
102 – Dissertation Prize Talk: Accretion driven outflows across the black hole mass scale, Ashley King (KIPAC/Stanford University)
103 – Time Domain Astronomy
104 – Feedback from Accreting Binaries in Cosmological Scales
105 – Stellar Compact I
106 – AGNs Poster Session
107 – Astroparticles, Cosmic Rays, and Neutrinos Poster Session
108 – Cosmic Backgrounds and Deep Surveys Poster Session
109 – Galactic Black Holes Poster Session
110 – Galaxies and ISM Poster Session
111 – Galaxy Clusters Poster Session
112 – Gamma-Ray Bursts Poster Session
113 – Gravitational Waves Poster Session
114 – Isolated Nss Poster Session
115 – Laboratory Astrophysics and Data Analysis Poster Session
116 – Missions & Instruments Poster Session
117 – Solar and Stellar Poster Session
118 – Supernovae and Supernova Remnants Poster Session
119 – WDs & CVs Poster Session
120 – XRBs and Population Surveys Poster Session
200 – Solar Wind Charge Exchange: Measurements and Models
201 – TeraGauss, Gigatons, and MegaKelvin: Theory and Observations of Accretion Column Physics
202 – The Structure of the Inner Accretion Flow of Stellar-Mass and Supermassive Black Holes
203 – Missing Baryons and the Hot Halo of the Milky Way
205 – Plenary Talk: Observation of Gravitational Waves in Advanced LIGO, Laura Cadonati (Georgia Tech)
206 – Early Results from the Astro-H Mission
207 – Stellar Compact II
300 – The Physics of Accretion Disks – A Joint HEAD/LAD Session
301 – Gravitational Waves
302 – Missions & Instruments
303 – Mid-Career Prize Talk: In the Ring with Circinus X-1: A Three-Round Struggle to Reveal its Secrets, Sebastian Heinz (Univ. of Wisconsin)
304 – Science of X-ray Polarimetry in the 21st Century
305 – Making the Multimessenger – EM Connection
306 – SNR/GRB/Gravitational Waves
400 – AGN II
401 – The Unique Role of Very High Energy Observations in Multi-Wavelength Astronomy
402 – Dark Matter, ISM, & Galaxies
403 – Rapporteur Plenary Talk

100 – AGN I

100.01 – An HST proper-motion study of the optical jet in 3C 264: Direct Evidence for the Internal Shock Model

Some of the most energetic phenomena in the Universe involve highly relativistic flows, in which particles are accelerated up to TeV energies. In the case of relativistic jets from Active Galactic Nuclei (AGN), these flows can carry enough energy to significantly influence both galactic and cluster evolution. While the exact physical mechanism that accelerates the radiating particles within the jet is not known, a widely adopted framework is the internal shock model, invoked to explain high-energy, non-thermal radiation from objects as diverse as microquasars, gamma-ray bursts, and relativistic jets in AGN. This model posits an unsteady relativistic flow that gives rise to components in the jet with different speeds. Faster components catch up to and collide with slower ones, leading to internal shocks. Despite its wide popularity as a theoretical framework, however, no occurance of this mechanism has ever been directly observed. We will present evidence of such a collision in a relativistic jet observed with the Hubble Space Telescope (HST) in the nearby radio galaxy 3C 264 (Meyer et al., 2015, Nature). Using images taken over 20 years, we show that a bright 'knot' in the jet is moving at an apparent speed of 7.0 +/- 0.8c and is in the incipient stages of a collision with a slow-moving knot (1.8 +/- 0.5c) just downstream. In the most recent epoch of imaging, we see evidence of brightening of the two knots as they commence their kiloparsec-scale collision. This is the behaviour expected in the internal shock scenario and the first direct evidence that internal shocks are a valid description of particle acceleration in relativistic jets.

Author(s): Eileen T. Meyer4, Markos Georganopoulos4, William B. Sparks3, Eric S. Perlman1, Roeland P. Van Der Marel3, Jay Anderson3, S. Tony Sohn2, John A. Biretta3, Colin Arthur Norman2, Marco Chiaberge3
Institution(s): *1. Florida Institute of Technology, 2. Johns Hopkins University, 3. Space Telescope Science Institute, 4. University of Maryland, Baltimore County*

100.02 – Multiwavelength Observations of AGN Jets: Untangling the Coupled Problems of Emission Mechanism and Jet Structure

The discovery of X-ray and optical emission from large numbers of AGN jets is one of the key legacies of the Chandra X-ray Observatory and Hubble Space Telescope. Several dozen optical and X-ray emitting jets are now known, most of which are seen in both bands as well as in the radio, where they were first discovered. Jets carry prodigious amounts of energy and mass out from the nuclear regions out to tens to hundreds of kiloparsecs distant from the central black hole, depositing it into the host galaxy and cluster. Interpreting their multiwavelength emissions has not been easy: while in most jets, the optical and radio emission in many objects is believed to emerge via the synchrotron process, due to its characteristic spectral shape and high radio polarization, the X-ray emission has been a tougher nut to crack. In less powerful, FR I jets, such as M87, the X-ray emission is believed to be synchrotron emission from the highest energy electrons, requiring in situ particle acceleration due to the short radiative lifetimes of the particles. However, in FR II and quasar jets, a variety of emission mechanisms are possible. Until the last few years, the leading interpretation had been inverse-Comptonization of Cosmic Microwave Background photons (the IC/CMB mechanism). This requires the jet to be relativistic out to hundreds of kiloparsecs from the nucleus, and requires an electron spectrum that extends to very low Lorentz factors. However, that now appears less likely, due to observed high optical polarizations in jets where the optical and X-ray emission appears to lie on the same spectral component, as well as limits derived from Fermi observations in the GeV gamma-rays. It now appears more likely that the X-rays must arise as synchrotron emission from a second, high energy electron population. With this revelation, we must tackle anew the coupling between jet structure and emission mechanisms. Multiwavelength imaging and polarimetry can give us clues to the locations of the radiating particles in each band, as well as their kinematics and the jet's structure. We discuss new work that describes how observations in several bands can be knit together to form a more coherent picture of jet physics.

Author(s): Eric S. Perlman1, Sayali S Avachat1, Devon Clautice1, Markos Georganopoulos3, Eileen Meyer3, Mihai Cara2
Institution(s): *1. Florida Institute of Technology, 2. Space Telescope Science Institute, 3. UMBC*

100.03 – New insights into AGN coronae

Active galactic nuclei (AGN) are some of the most energetic sources of radiation in the Universe. The conversion of gravitational energy into radiation is thought to take place in an accretion disk/corona system just outside the black hole. In this system thermal, UV/optical photons from the accretion disk are upscattered in a corona of hot electrons situated above the accretion disk producing X-rays. The nature of this Comptonizing corona remains a key open question in AGN physics. The NuSTAR satellite provides the opportunity to study the Comptonization spectrum produced by the corona in great detail. In our talk we will show some key results from these new studies of the Comptonization spectrum. We explore how, together with our growing knowledge of coronal sizes, we are able to draw first conclusions about the physics taking place in the corona. We find evidence for coronae to be hot and radiatively compact, putting them close to the boundary of the region in the compactness–temperature diagram which is forbidden due to runaway pair production. This suggests that pair production and annihilation are essential ingredients in the coronae of AGN and that they control the coronal temperature and shape of the observed spectra.

Author(s): Anne Lohfink2, Andrew C Fabian2, Julien Malzac1, Renaud Belmont1, Douglas Buisson2
Institution(s): *1. Universite de Toulouse, 2. University of Cambridge*

100.04 – Chandra solves the mystery: Understanding the UV anomaly discovered by HST

A strange anomaly was discovered during our 180 day HST campaign to observe NGC5548 for reverberation mapping. The UV emission lines responded to changes in the UV continuum, as they should, during most of
the observing season. However, there was a period of about 60--70 days during which the UV emission lines decorrelated from continuum variations. Understanding this anomaly is vital to the success of reverberation mapping technique. We also observed the source 4 times with Chandra during the 180 day HST observations. Chandra observations revealed the presence of soft excess during the anomaly, but there was no soft excess before or after the anomaly. This suggests that the accretion disk temperature increased from the ``normal'' state, peaking in FUV, to that peaking in soft X-rays during the anomaly. Thus, there was no ionizing continuum to which to reverberate. There are more curious things about the response of emission lines, such as the time at which the anomaly sets in and the amount flux decrease during the anomaly. I will discuss the details of this first-of-its-kind behavior and present detailed explanation.

Author(s): Smita Mathur1, Anjali Gupta1
Institution(s): *1. The Ohio State University*

100.05 – A New Look at Ionized Disk Winds in Seyfert-1 AGN

We present an analysis of deep, high signal-to-noise *Chandra*/HETG observations of four Seyfert-1 galaxies with known warm absorbers (outflowing winds), including NGC 4151, MCG-6-30-15, NGC 3783, and NGC 3516. Focusing on the 4-10 keV Fe K-band, we fit the spectra using grids of models characterized by photoion- ized absorption. Even in this limited band, the sensitive, time-averaged spectra all require 2-3 zones within the outflow. In an improvement over most previous studies, re-emission from the winds was self-consistently included in our models. The broadening of these emission components, when attributed to Keplerian rotation, yields new launching radius estimations that are largely consistent with the broad-line region. If this is correct, the hot outflow may supply the pressure needed to confine clumps within the broad-line region. NGC 4151 and NGC 3516 each appear to have a high-velocity component with speeds comparable to 0.01c. The winds in each of the four objects have kinetic luminosities greater than 0.5% of the host galaxy bolometric luminosity for a filling factor of unity, indicating that they may be significant agents of AGN feedback.

Author(s): Allison Bostrom[1], Jon M. Miller[1]
Institution(s): *1. University of Michigan*

100.06 – Relativistic reverberation in the accretion flow of a Tidal Disruption Event

Our current understanding of the curved spacetime around supermassive black holes is based on actively accreting black holes, which make up only ten per cent or less of the overall population. X-ray observations of that small fraction reveal strong gravitational redshifts that indicate that many of these black holes are rapidly rotating, however selection biases suggest that these results of a few are not necessarily reflective of the majority of black hole spins in the Universe. Tidal disruption events, where a star orbiting an otherwise dormant black hole gets tidally shredded and accreted on to the black hole, can provide a short, unbiased glimpse at the spacetime around the other ninety per cent of black holes. Observations of tidal disruptions have hitherto revealed the formation of an accretion disc and the onset of an accretion-powered jet, but have failed to reveal gravitational redshifts from innermost regions close to the event horizon, which enable the measurement of black hole spin. Here, we report observations of reverberation arising from photons from highly ionized iron (from K shell electrons) reflected off the accretion flow in a tidal disruption event. The asymmetric iron line profile indicates that we are seeing a region close to the event horizon of the black hole, where gravitational redshifts are strong. From the reverberation time delay, we estimate the mass of the central black hole to be a few million solar masses. Combined with the observed luminosity, we conclude the tidal disruption event is accreting at least 100 times the Eddington limit, which is consistent with predictions of the mass fallback rate of a tidally disrupted star. The detection of reverberation from the relativistic depths of this rare hyper-Eddington event demonstrates that the X-rays do not arise from the relativistically moving regions of a jet, as previously thought.

Author(s): Erin Kara[1], Jon M. Miller[2], Christopher S. Reynolds[1], Lixin J. Dai[1]
Institution(s): *1. University of Maryland, 2. University of Michigan*

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101 – Galaxy Clusters

101.01 – A Deep Chandra Observation of NGC 1404: the Best Constraints on the Transport Processes in the Intracluster Medium

The intracluster medium, as a magnetized and highly ionized fluid, provides an ideal laboratory to study plasma physics. We present results from the Chandra X-ray observation of NGC 1404, a bright elliptical galaxy falling through the ICM of the Fornax Cluster. The hot, gaseous corona surrounding NGC 1404 is characterized by a sharp upstream edge and a downstream gaseous tail. We resolve the scales of contact discontinuities down to an unprecedented level due to the combination of the proximity of NGC 1404, the superb spatial resolution of Chandra, and a very deep (670 ksec) exposure. We observed Kelvin-Helmholtz instability (KHI) rolls and put an upper limit on the viscosity of hot cluster plasma. We also observed a mixing between the hot cluster gas and the cold galaxy gas in the downstream stripped tail, providing further support of a low viscosity plasma. Across the upstream front, we measured a discontinuity smaller than the mean free path. The magnetic field is strong enough to suppress electron diffusions but weak enough to allow KHI rolls unsuppressed. Our simulation, tailored to the specific scenario, will provide further insight into the details of the transport process.

Author(s): Ralph P. Kraft[1], Yuanyuan Su[1], Paul Nulsen[1], Elke Roediger[2], William R. Forman[1], Eugene Churazov[3], Christine Jones[1], Scott W. Randall[1], Marie E. Machacek[1]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. Hull University, 3. MPA*

101.02 – Exploring the Outskirts of the Galaxy Cluster Merger A1750 Along the Putative Large-Scale Filament

The entropy profiles in the outskirts of clusters generally fall below the self-similar prediction based on purely gravitational models of hierarchical cluster formation. Weakening accretion shocks and the presence of unresolved cool gas clumps, both of which are expected to correlate with large-scale structure filaments, are among the possible interpretations of observed entropy flattening. A1750 is a triple merger system, with all three subclusters lying roughly along the same line, suggesting the presence of large-scale structure filament. Our recent Suzaku and Chandra X-ray, and MMT optical observations of the early stage galaxy cluster merger A1750 show that entropy profiles at the cluster's virial radius are self-similar and gas mass fractions are consistent with the mean cosmic value both along and perpendicular to the putative large scale filament. These results may suggest that gas clumping is less prevalent in lower temperature and mass clusters. I will also describe the properties of the cool (< 1 keV) gas detected at large cluster radii along the filament direction, which is consistent with the expected properties of the denser, hotter phase of the WHIM.

Author(s): Esra Bulbul[5], Scott W. Randall[4], Matthew Bayliss[4], Eric Miller[5], Felipe Andrade-Santos[4], Ryan Johnson[3], Mark W. Bautz[5], Elizabeth L. Blanton[2], William R. Forman[4], Christine Jones[4], Rachel Paterno-Mahler[6], Stephen S. Murray[4], Craig L. Sarazin[7], Randall K. Smith[4], Cemile Ezer[1]
Institution(s): *1. Bogazici Univ, 2. Boston Univ., 3. Gettysburg College, 4. Harvard-Smithsonian Center for Astrophysics, 5. MIT, 6. University of Michigan, 7. University of Virginia*

101.03 – AGN feedback in the Perseus cluster

Deep Chandra images of the Perseus cluster of galaxies have revealed a succession of cavities created by the jets of the central supermassive black hole, pushing away the X-ray emitting gas and leaving bubbles filled with radio emission. Perseus is one of the rare examples showing buoyantly rising lobes from past radio outbursts, characterized by a steep spectral index and known as ghost cavities. All of these structures trace the complete history of mechanical AGN feedback over the past 500 Myrs. I will present results on new, ultra deep 230-470 MHz JVLA data. This low-frequency view of the Perseus cluster will probe the old radio-emitting electron population and will allow us to build the most detailed map of AGN feedback in a cluster thus far.

Author(s): Marie-Lou Gendron-Marsolais[4], Julie Hlavacek-Larrondo[4], Tracy E. Clarke[2], Huib Intema[1], Andrew C Fabian[3], Gregory B. Taylor[5], Katherine Blundell[6]
Institution(s): *1. Leiden Observatory, Universiteit Leiden, 2. Naval Research Laboratory, 3. University of Cambridge, 4. University of Montreal, 5. University of New-Mexico, 6. University of Oxford*

101.04 – Microphysics of intracluster plasma with an X-ray microcalorimeter

Our usual assumption of a Maxwellian distribution for thermal electrons in the intracluster plasma may be incorrect, as evidenced by in-situ observations in the solar wind plasma. Strong deviations are possible, and even likely, in cluster locations where cosmic ray acceleration should be occurring as seen from the resulting synchrotron radio emission, such as radio halos and relics. Recent theoretical work shows that such non-Maxwellian electron distributions would alter the ionization balance and emission line ratios for various elements, and even the shape of thermal continuum that we use for cluster temperature determination. The Astro-H microcalorimeter will be able to detect such deviations if the bulk of the intracluster plasma is non-Maxwellian, and future high angular resolution microcalorimeters will be able to study such deviations at shock fronts, radio relics and other special locations.

Author(s): Maxim L. Markevitch[2], Lynn Wilson[2], Thomas W. Jones5, Dongsu Ryu4, Gianfranco Brunetti[1], Siang P. Oh3
Institution(s): *1. IRA/INAF, 2. NASA GSFC, 3. UCSB, 4. UNIST, 5. Univ. Minnesota*

101.05 – Kinetic Modeling of Electron Conduction-Driven Microinstabilities and Their Relevance for AGN Feedback

Since the Intracluster Medium (ICM) is a weakly collisional plasma, the standard Spitzer conduction rate (which relies on collisionality) does not necessarily describe the transport of heat in clusters. In addition, many plasma microinstabilities become unstable at high beta since the magnetic field is easily pliable in the presence of induced pressure anisotropies. These properties imply that the true rate of conduction in an ICM-like plasma could be highly dependent on small-scale effects. We perform 2D kinetic Particle-In-Cell simulations and derive an analytic theory of a conduction-driven electron microinstability present in high-beta collisionless plasmas. We find that scattering by electromagnetic waves significantly reduces the conductive heat flux of electrons in our model. Our results have implications for 1) cool-core clusters in which AGN feedback may play a crucial role in maintaining overall thermodynamic stability, 2) heat flux suppression and scattering by other microinstabilities and 3) basic plasma physics questions that up until this point have not been explored fully.

Author(s): Gareth Roberg-Clark[1], M. Swisdak[1], Christopher S. Reynolds[1], James Drake[1]
Institution(s): *1. University of Maryland, College Park*

102 – Dissertation Prize Talk: Accretion driven outflows across the black hole mass scale, Ashley King (KIPAC/Stanford University)

102.01 – Accretion driven outflows across the black hole mass scale

Pumping highly relativistic particles and radiation into their environment, accreting black holes co-evolve with their surroundings through their powerful outflows. These outflows are divided into highly collimated, relativistic jets and wide-angle winds, and are primarily associated with a particular accretion states. Understanding just how these outflows couple to the accretion flow will enable us to assess the amount of energy and feedback that is injected into the vicinity of a black hole. During this talk, I will discuss our studies of both stellar-mass and supermassive black hole outlfows, and how the similarities of these flows across the mass scale may point to common driving mechanisms.

Author(s): Ashley L. King[1]
Institution(s): *1. KIPAC/Stanford University*

103 – Time Domain Astronomy

103.01 – Young Supernova explosions in the X-rays and hard X-rays

X-ray observations are providing critical insights into Supernova explosions and the nature of their progenitors. In this talk I will highlight some recent results from our dedicated programs at high-energies that allowed us to (1) uncover the weakest engine-driven SNe and understand their link to Gamma-Ray Bursts; (2) monitor the high-energy emission from shock energy deposition into the stellar envelope as early as a few days after the onset of core-collapse; (3) put the most stringent constraints to the progenitors of Type Ia SNe by using the deepest X-ray observations ever obtained. (4) Reveal the ejection of a massive stellar envelope timed with the collapse of a stripped star. These observations represent the first solid detection of a young extragalactic stripped-envelope SN out to high-energy X-rays of ~40 keV

Author(s): Raffaella Margutti[1]
Institution(s): *1. New York University*

103.02 – Observational Constraints on the Supernova Engine

Over the past 4 decades, the proposed engine behind normal core-collapse supernova has evolved considerably with increasingly detailed models. These models produce increasingly firm predictions of the nature of these explosions. Unfortunatley, there is a level of indirection connecting these predictions to actual observations. Here we review the current observational constraints on the supernova engine (and its underlying physics).

Author(s): Chris Fryer[1]
Institution(s): *1. LANL*

103.03 – Flares from stars tidally disrupted by supermassive black holes

Stellar tidal disruption events are unique probes of accretion physics and disk winds under extreme conditions. Their luminous flares of radiation are signposts of intermediate-mass black holes (BHs) and recoiling BHs. In X-rays, they have the potential to probe GR effects near the last stable orbit. Some of the events launch relativistic jets, and provide us with a powerful new method of understanding the physics of jet formation and evolution in a quiescent environment. About 30-40 candidate events have been identified by now, mostly in the X-rays and the optical. Events will be detected in the thousands in upcoming sky surveys, enabling statistical studies and rapid multi-wavelength follow-ups. Here, I provide a review of the field, including most recent results.

Author(s): St. Komossa[1]
Institution(s): *1. Max-Planck-Institut fuer Radioastronomie*

103.05 – Explorer for Transient Astrophysics: an X-ray transient mission for the 2020s

Explorer for Transient Astrophysics (ETA) is a wide-field X-ray transient mission proposed for flight starting in 2023. Through its unique imaging X-ray optics that allow a 30 deg by 20 deg FoV in three separate modules, a 1 arc min position resolution and a 10^{-11} erg/(sec cm^2) sensitivity in 2000 sec, ETA will observe numerous events per year of X-ray transients related to compact objects, including: tidal disruptions of stars, supernova shock breakouts, neutron star bursts and superbursts, high redshift Gamma-Ray Bursts, and perhaps most exciting, X-ray counterparts of gravitational wave detections involving stellar mass and possibly supermassive black holes. The mission includes an IR Telescope that allows on-board redshift determination of gamma-ray bursts, and a small gamma-ray burst monitor to be contributed by the Technion (Israel Institute of Technology.)

Author(s): Jordan Camp[1]
Institution(s): *1. NASA/GSFC*

103.06 – Time Domain X-ray Astronomy with "All-Sky" Focusing Telescopes

The largest and most diverse types of temporal variations in all of astronomy occur in the soft, i.e. 0.5 to 10 keV, X-ray band. They range from millisecond QPO's in compact binaries to year long flares from AGNs due to the absorption of a star by a SMBH, and the appearance of transient sources at decadal intervals. Models predict that at least some gravitational waves will be accompanied by an X-ray flare. A typical GRB produces more photons/sq. cm. in the soft band than it does in the Swift BAT 15 to 150 keV band. In addition the GRB X-ray fluence and knowledge of the details of the onset of the X-ray afterglow is obtained by observing the seamless transition from the active burst phase that has been attributed to internal shocks to the afterglow phases that has been attributed to external shocks. Detecting orphan X-ray afterglows will augment the event rate. With high sensitivity detectors some GRB identifications are likely to be with the youngest, most distant galaxies in the universe. Previous all-sky X-ray monitors have been non focusing limited field of view scanning instruments. An "All-Sky" (actually several ster FOV), focusing lobster-eye X-ray telescope will have much more grasp than the previous instruments and will allow a wide range of topics to be studied simultaneously. Two types of lobster-eye telescopes have been proposed. One type focuses in one dimension and uses a coded mask for resolution in the second. The other type focuses in two dimensions but has less effective area and less bandwidth. Both types are compatible with a Probe mission.

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

104 – Feedback from Accreting Binaries in Cosmological Scales

104.01 – Accreting binary population synthesis and feedback prescriptions

Studies of extagalactic X-ray binary populations have shown that the characteristics of these populations depend strongly on the characteristics of the host galaxy's parent stellar population (e.g. star-formation history and metallicity). These dependencies not only make X-ray binaries promising for aiding in the measurement of galaxy properties themselves, but they also have important astrophysical and cosmological implications. For example, due to the relatively young stellar ages and primordial metallicities in the early Universe (z > 3), it is predicted that X-ray binaries were more luminous than today. The more energetic X-ray photons, because of their long mean-free paths, can escape the galaxies where they are produced, and interact at long distances with the intergalactic medium. This could result in a smoother spatial distribution of ionized regions, and more importantly in an overall warmer intergalactic medium. The energetic X-ray photons emitted from X-ray binaries dominate the X-ray radiation field over active galactic nuclei at z > 6 - 8, and hence X-ray binary feedback can be a non-negligible contributor to the heating and reionization of the inter-galactic medium in the early universe. The spectral energy distribution shape of the XRB emission does not change significantly with redshift, suggesting that the same XRB subpopulation, namely black-hole XRBs in the high–soft state, dominates the cumulative emission at all times. On the contrary, the normalization of the spectral energy distribution does evolve with redshift. To zeroth order, this evolution is driven by the cosmic star-formation rate evolution. However, the metallicity evolution of the universe and the mean stellar population age are two important factors that affect the X-ray emission from high-mass and low-mass XRBs, respectively. In this talk, I will review recent studies on the potential feedback from accreting binary populations in galactic and cosmological scales. Furthermore, I will discuss which are the next steps towards a more physically realisitc modelling of accreting compact object populations in the early Universe.

Author(s): Tassos Fragos[1]
Institution(s): *1. Geneva Observatory, University of Geneva*

104.02 – X-ray Evolution of Normal Galaxies in the 6 Ms Chandra Deep Field-South

I will discuss recent efforts to quantify the evolution of X-ray binary (XRB) populations through cosmic time using the 6 Ms Chandra Deep Field-South (CDF-S) survey. The formation of XRBs is sensitive to galaxy properties like stellar age and metallicity---properties that have evolved significantly in the broader galaxy population throughout cosmic history. I will show that scaling relations between X-ray emission from low-mass XRBs (LMXBs) with stellar mass (LX/M) and high-mass XRBs (HMXBs) with star-formation rate (LX/SFR) change significantly with redshift, such that LX(LMXB)/M ~ (1+z)^2-3 and LX(HMXB)/SFR ~ (1+z). These findings are consistent with population synthesis models, which attribute the increase in LMXB and HMXB scaling relations with redshift as being due to declining host galaxy stellar ages and metallicities, respectively. These findings have important implications for the X-ray emission from young, low-metallicity galaxies at high redshift, which are likely to be more X-ray luminous per SFR and play a significant role in the heating of the intergalactic medium.

Author(s): Bret Lehmer[11], Antara Basu-Zych[6], Stefano Mineo[5], W. Niel Brandt[8], Rafael T. Eufrasio[11], Tassos Fragos[1], Ann E. Hornschemeier[6], Bin Luo[8], Yongquan Xue[14], Franz E. Bauer[9], Marat Gilfanov[5], Vassiliki Kalogera[7], Piero Ranalli[2], Donald P. Schneider[8], Ohad Shemmer[13], Paolo Tozzi[3], Jonathan R. Trump[8], Cristian Vignali[12], JunXian Wang[14], Mihoko Yukita[4], Andreas Zezas[10]
Institution(s): *1. Geneva Observatory, 2. IAASARS, 3. INAF, 4. Johns Hopkins University, 5. MPA, 6. NASA GSFC, 7. Northwestern, 8. Penn State, 9. Pontifica Catolica de Chile, 10. SAO, 11. University of Arkansas, 12. University of Bologna, 13. University of North Texas, 14. University of Science and Technology of China*

104.04 – Studying the first X-ray sources in our Universe with the redshifted 21-cm line

The cosmological 21-cm line is sensitive to the thermal and ionization state of the intergalactic medium (IGM). As it is a line transition, a given observed frequency can be associated with a cosmological redshift. Thus upcoming next-generation radio interferometers, such as HERA and SKA, will map out the 3D structure of the early Universe. This 21-cm signal encodes a weath of information about the first galaxies and IGM structures. In particular, X-ray sources in the first galaxies are thought to have heated the IGM to temperatures above the CMB temperature, well before cosmic reionization. The spatial structure of the 21-cm signal during this epoch of X-ray heating encodes invaluable information about the X-ray luminosity and spectral energy distributions of the first galaxies. I will review this exciting new fronteer, highlighting how the 21-cm line will provide us with a unique opertunity to study high-energy processes inside the first galaxies.

Author(s): Andrei Mesinger[1]
Institution(s): *1. Scuola Normale Superiore*

105 – Stellar Compact I

105.01 – New Insights from Phase-Resolved Spectroscopy of QPOs in GX 339—4

We present a new spectral-timing technique for phase-resolved spectroscopy of low-frequency Type B quasi-periodic oscillations (QPOs) from the black hole X-ray binary GX 339--4. Evidence suggests that low-frequency QPOs originate from near-periodic geometric changes in the inner accretion flow, possibly due to general relativistic precession. The physical model predicts spectral energy distribution changes on the QPO timescale, but it is not possible to probe these changes using strictly spectral or timing analysis. Our new technique shows that for these data, the spectral energy distribution changes not only in normalization, but in spectral shape also, on the QPO timescale. We find that a blackbody spectral component and power law spectral component are both required to vary on the QPO timescale, and the blackbody variations are out of phase with the power law. With these findings we suggest a geometry for the precessing flow in the strong-gravity regime close to black holes.

Author(s): Abigail L Stevens[1], Phil Uttley[1], Michiel van der Klis[1]
Institution(s): *1. University of Amsterdam*

105.02 – Detection of Quasi-Periodic Oscillations in the June 2015 Outburst of V404 Cygni

In June 2015, the black hole X-ray binary (BHXRB) V404 Cygni

went into outburst for the first time in 26 years. The source is not only the closest known BHXRB, it is also known to undergo extreme variations in brightness, allowing us to study the source's behaviour during flaring with the unprecedented detail afforded by modern space and ground-based instrumentation.
Here we present a timing study and a comprehensive search for quasi-periodic oscillations (QPOs) of V404 Cygni during its most recent outburst, utilizing data from six instruments on board five different X-ray missions: Swift/XRT, Fermi/GBM, Chandra/ACIS, INTEGRAL's IBIS/ISGRI and JEM-X, and NuSTAR.
We find four previously unobserved, significant QPOs throughout the outburst. One QPO, at 18 mHz, is detected in simultaneous observations with both Fermi/GBM and Swift/XRT, and is a likely example of a rare, recently discovered class of mHz-QPOs in BHXRBs linked to high-inclination sources. We also find a broad structure in averaged periodograms of several Chandra/ACIS and INTEGRAL/JEM-X observations that contains significant variability, but is too broad to be called a QPO, reminiscent of a feature more commonly observed in Cygnus X-1. We discuss our results in the context of current models for QPO formation.

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105.03 – A Repeating Fast Radio Burst: Radio and X-ray Follow-up Observations of FRB 121102

A new phenomenon has emerged in high-energy astronomy in the past few years: the Fast Radio Burst. Fast Radio Bursts (FRBs) are millisecond-duration radio bursts whose dispersion measures imply that they originate from far outside of the Galaxy. Their origin is as yet unknown; their durations and energetics imply that they involve compact objects, such as neutron stars or black holes. Due to their extreme luminosities implied by their distances and the previous absence of any repeat burst in follow-up observations, many potential explanations involve one-time cataclysmic events. However, in our Arecibo telescope follow-up observations of FRB 121102 (discovered in the PALFA survey; Spitler et al. 2014), we find additional bursts at the same location and dispersion measure as the original burst. We also present the results of Swift and Chandra X-ray observations of the field. This result shows that, for at least a sub-set of the FRB population, the source can repeat and thus cannot be explained by a cataclysmic origin.

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105.04 – Unexpected Windy Weather Around a Highly Magnetized Neutron Star

Magnetars and rotation-powered pulsars (RPPs) historically represented two distinct subclasses of neutron stars. Magnetars are slowly-rotating (~2-12 s), isolated neutron stars (NSs) with super-strong magnetic fields, B~10^13-10^15 G. RPPs, on the other hand, are rapidly-rotating (~0.01-0.3~s), isolated NSs with surface dipole magnetic field in the range ~10^11-10^13 G. Most pulsars possess a large rotational energy loss rate that powers a relativistic magnetized particle wind, often seen as a pulsar wind nebula (PWN; the Crab PWN being the most famous). There has not yet been convincing evidence for a wind nebula around magnetars, most likely due to their low rotational energy loss rate. Here, we report the study of new deep X-ray observations of the peculiar extended emission around the magnetar Swift J1834.9-0846. Our new results strongly support a wind nebula as the nature of the extended emission, thus, establishing Swift J1834.9-0846 as the first magnetar to possess a surrounding nebula. This implies that wind nebulae are no longer exclusive to RPPs and, along with recent discoveries in the field, further narrow the gaps between these two sub-populations of isolated NSs. The physical properties of this wind nebula, however, show peculiarities, especially its high radiative efficiency of about 10%, only shared with two other known very young RPPs, the Crab and its twin.

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105.05 – Constraining the State of Ultra-dense Matter with the Neutron Star Interior Composition Explorer

[This presentation is submitted on behalf of the entire NICER Science Team] The state of cold matter at densities exceeding those of atomic nuclei remains one of the principal outstanding problems in modern physics. Neutron stars provide the only known setting in the universe where these physical conditions can be explored. Thermal X-ray radiation from the physical surface of a neutron star can serve as a powerful tool for probing the poorly understood behavior of the matter in the dense stellar interior. For instance, realistic modeling of the thermal X-ray modulations observed from rotation-powered millisecond pulsars can produce stringent constraints on the neutron star mass-radius relation, and by extension the state of supra-nuclear matter. I will describe the prospects for precision neutron star equation of state constraints with millisecond pulsars using the forthcoming Neutron Star Interior Composition Explorer (NICER) X-ray timing mission.

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105.06 – X-ray Pulsation Searches with NICER

The Neutron Star Interior Composition Explorer (NICER) is an X-ray telescope with capabilities optimized for the study of the structure, dynamics, and energetics of neutron stars through high-precision timing of rotation- and accretion-powered pulsars in the 0.2–12 keV band. It has large collecting area (twice that of the XMM-Newton EPIC-pn camera), CCD-quality spectral resolution, and high-precision photon time tagging referenced to UTC through an onboard GPS receiver. NICER will begin its 18-month prime mission as an attached payload on the International Space Station around the end of 2016. I will describe the science planning for the pulsation search science working group, which is charged with searching for pulsations and studying flux modulation properties of pulsars and other neutron stars. A primary goal of our observations is to detect pulsations from new millisecond pulsars that will contribute to NICER's studies of the neutron star equation of state through pulse profile modeling. Beyond that, our working group will search for pulsations in a range of source categories, including LMXBs, new X-ray transients that might be accreting millisecond pulsars, X-ray counterparts to unassociated Fermi LAT sources, gamma-ray binaries, isolated neutron stars, and ultra-luminous X-ray sources. I will survey our science plans and give an overview of our planned observations during NICER's prime mission.

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106 – AGNs Poster Session

106.01 – Rapid Gamma-Ray and Optical Variability in Bright Fermi Blazars

Using an "aperture photometry" technique to generate Fermi lightcurves on minute timescales, we have searched the brightest blazar flares for variability down to ~10 minute timescales. We find evidence for strong gamma-ray variability down to ~1 - 2 hour timescales, but not on ~10-30 minute timescales even though the photon statistics are sufficient to detect it. Using SMARTS optical/NIR, we then search for correlated rapid optical variability on similar timescales. While variability on these very short timescales is detected in a few cases, the optical variability amplitude is typically much *smaller* than the gamma-ray one. Interestingly, on ~1-3 daytimescales the optical and gamma-ray variability are instead well-correlated and of similar amplitude. We discuss the implications of this variability behavior for blazar modeling.

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106.02 – Imaging AGN Feedback in NGC 3393 with CHEERS

The CHandra Extended Emission-line Region Survey (CHEERS) is the 'ultimate' resolution X-ray imaging survey of nearby far-IR selected AGN. By comparing deep Chandra observations with complementary HST and radio data, we investigate the morphology of the extended narrow-line region on scales of <100 pc. We present new results on the gas surrounding the compton-thick AGN NGC 3393. The luminous extended narrow-line X-ray emission from this gas allows us to study the role and extent of AGN feedback as sub-kpc jets interact with the surrounding ISM.

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106.03 – Exploring the Variability Characteristics of the Fermi AGN Sample

The Fermi Gamma-Ray Space Telescope (*Fermi*) has cataloged over 3000 gamma-ray *(>100 MeV*) point sources of which ~70% are likely AGN. The AGN are predominantly representative of the radio-loud “blazar” subclass. The emission from these objects is known to be dominated by relativistic beaming and is almost always variable, often exhibiting high-amplitude flaring. To date there have been numerous studies of individual objects including multi-wavelength campaigns with some including parsec-scale radio jet morphological studies. These studies have led to new insight in to our understanding of the blazar phenomena and jet propagation. However, there remains a dearth of statistical information on the variability characteristics of the population in aggregate. What, for example, are the distributions of flare amplitudes, durations, temporal profiles and recurrence histories among the gamma-ray blazar subclasses? We present some results of our study of a large (~103) set of gamma-ray light curves. For the brightest subset we explore in greater detail their properties such as morphologies and their rise and decay timescales. We include where plausible the associated energy dependencies of these rise and decay profiles. We discuss our results in terms of the possible implications on the scale and location of jet structures associated with the emission sites and the cooling timescales of the electron population producing the gamma rays.

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106.04 – The Population of Gamma-Ray Loud NLSy1 Galaxies With Blazar-Like Properties

We report an investigation of the blazar-like properties for a subset of a sample of radio-loud NLSy1 galaxies. Using the properties of rapid and large amplitude optical and radio variability, rapid and large amplitude variations in the optical polarization and position angle, and choosing a sample that is very radio loud (R > 100), we find that that one can identify a sample of NLSy1 galaxies which exhibit properties, such as gamma ray emission, that are thought to be characteristic of the presence of relativistic jets oriented near the line-of-sight to the observer. As a result, we report the identification a number of newly discovered gamma-ray loud NLSy1 galaxies found in the Fermi database.

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106.05 – KSwAGS: A Swift X-Ray and UV Survey of the Kepler and K2 Fields

We present the first phase of the Kepler-Swift Active Galaxies and Stars survey (KSwAGS), a simultaneous X-ray and UV survey of 6 square degrees of the Kepler field. Kepler/K2 is the most precise photometer of our time, producing exquisite light curves of both stellar targets and active galaxies. We detect 93 unique X-ray sources with signal-to-noise ratio > 3 with the XRT, of which 60 have UV counterparts. The survey produces a mixture of stellar sources, extragalactic sources, and sources which we are not able to classify with certainty. We have obtained optical spectra for a majority of these targets, providing necessary parameters for study of the light curves in an astrophysical context; for example, surface gravities and rotation velocities for stars, and black hole mass estimates for AGN. Our survey provides the first X-ray and UV data for a number of known variable stellar sources, as well as a large number of new X-ray detections in this well-studied portion of the sky. The KSwAGS survey is currently ongoing in the K2 ecliptic plane fields, and provides a wide array of X-ray selected targets for photometric study with archival Kepler light curves and new data from K2.

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106.06 – Determining the X-ray Emission Mechanism for the Large-Scale Quasar Jet of 3C 111

Relativistic jets from active galactic nuclei (AGN) are powerful phenomena that transport prodigious amounts of energy and mass from the core of a galaxy out to kiloparsec or even megaparsec distances. While most spatially-resolved jets are seen in the radio, an increasing number have been discovered to emit in the optical/near-IR and/or X-ray bands. Here we discuss a spectacular example of this class, the 3C 111 jet, housed in one of the nearest, double-lobed FR II radio galaxies known. The jet itself extends over 100 kpc on each side, making it one of the longest to be seen in the radio, near-IR/optical and X-ray bands. Its length and straight nature makes it ideal for studying jet physics over many kiloparsecs. We discuss new, deep Chandra and HST observations that reveal both near-IR and X-ray emission from several components of the 3C 111 jet, as well as both the approaching and receding hotspots. The near-IR and X-ray emission in the jet is restricted to several knots, and there are important differences between the morphologies seen in the radio, near-IR, and X-ray bands. In several jet regions we detect X-ray maxima significantly upstream of the radio maxima. We analyze the broad-band spectral energy distributions of the jet components and the X-ray spectra of the brightest regions. We compare competing models of emission as they relate to frequency-dependent relativistic beaming. The morphological differences coupled with the X-ray spectral slopes lead us to favor the two-component synchrotron model and disfavor the IC/CMB model.

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106.07 – Dramatic long-term X-ray variability in AGNs

Dramatic X-ray and optical variability on ~ 10 year timescales has been discovered recently in a handful of quasars, which may provide important new insight into the issue of how luminous AGNs are fueled. We have assembled a new sample of extremely variable X-ray sources from archival *Einstein* and *ROSAT* data that could increase substantially the number of such objects known. The sources in our sample varied in X-ray flux by at least a factor of 7–8 over a 10-year span, and most exhibited significantly larger variability amplitudes (10 to over 100). We present the details of how our sample was assembled and preliminary results regarding the identifications, properties, and X-ray histories of the objects. Although a heterogeneous population is expected, some sources in the sample are associated with broad-line AGNs, including a radio-quiet quasar at z = 1.3 that decreased in X-ray luminosity by a factor of 40.

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106.08 – The Vertical Structure of Nuclear Starburst Disks: Testing a Model of AGN Obscuration

Nuclear starburst disks are Eddington-limited, radiation pressure supported disks that may be active in the nuclear environment of active galaxies (ULIRGS and AGNs). Earlier analytical models suggested that, under certain conditions, these disks may be geometrically thick on pc-scales, and thus could be a viable source for AGN obscuration, partcularly at z≤1, when gas factions in galaxies are still significant. Here, we present early results from numerical 2D models of nuclear starburst disks where the vertical structure is calculated explicitly from solving the hydrostatic balance and radiative transfer equations. We quantitatively assess under which conditions the starburst disk may present substantial obscuring columns for AGN observations.

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106.09 – The Intrinsic Eddington Ratio Distribution of Active Galactic Nuclei in Young Galaxies from SDSS

An important question in extragalactic astronomy concerns the distribution of black hole accretion rates, i.e. the Eddington ratio distribution, of active galactic nuclei (AGN). Specifically, it is matter of debate whether AGN follow a broad distribution in accretion rates, or if the distribution is more strongly peaked at characteristic Eddington ratios. Using a sample of galaxies from SDSS DR7, we test whether an intrinsic Eddington ratio distribution that takes the form of a broad Schechter function is in fact consistent with previous work that suggests instead that young galaxies in optical surveys have a more strongly peaked lognormal Eddington ratio distribution. Furthermore, we present an improved method for extracting the AGN distribution using BPT diagnostics that allows us to probe over one order of magnitude lower in Eddington ratio, counteracting the effects of dilution by star formation. We conclude that the intrinsic Eddington ratio distribution of optically selected AGN is consistent with a power law with an exponential cutoff, as is observed in the X-rays. This work was supported in part by a NASA Jenkins Fellowship.

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106.10 – MHD-based modeling of radiation and polarization signatures of blazar emission

Observations have shown that sometimes strong multiwavelength flares are accompanied by drastic polarization variations, indicating active participation of magnetic fields during flares. We have developed a 3D numerical tool set of magnetohydrodynamics, Fokker-Planck particle evolution, and polarization-dependent radiation transfer codes. This allows us to study the snap-shot spectra, multiwavelength light curves, and time-dependent optical polarization signatures self-consistently. We have made a simultaneous fit of a multiwavelength flare with 180 degree polarization angle swing of the blazar 3C279 reported by Abdo et al. 2010. Our work has shown that this event requires an increase in the nonthermal particles, a decrease in the magnetic field strength, and a change in the magnetic field structure. We conclude that this event is likely due to a shock-initiated magnetic reconnection in an emission environment with relatively strong magnetic energy. We have performed magnetrohydrodynamic simulations to support this statement. Our simulations have found that the blazar emission region may be strongly magnetized. In this situation, polarization angle swings are likely to be correlated with strong gamma-ray flares.

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106.11 – Multi-wavelength polarimetry and variability study of M87 jet during 2003-2008

We present the multi-wavelength study of M87's jet . We compare the radio and optical polarimetry and variability and attempt to study the spectrum of the jet in radio through X-rays wavelengths. By comparing the data with previously published VLA and HST observations, we show that the jet's morphology in total and polarized light is changing significantly on timescales of ~1 decade. We are looking for the variability of different knots and changes in their spectra using our deep, high resolution observations of the jet between 2003 and 2008. The observations have 2-3 times better resolution that any similar previous study (Perlman et al. 1999) in addition allowing us to observe variability. During this time, the nucleus showed month-scale variability in optical and X-rays and also flared twice in all wave- lengths including radio. The knot HST-1, located closest to the nucleus, displayed a huge flare, increasing about 100 times in brightness. The knot A and B complex shows variations in polarization structures indicating the presence of a helical magnetic field which may be responsible for the in-situ particle accelerations in the jet. We compare the evolution of different knots and components of the jet, when our observations overlap with the multi-wavelength monitoring campaigns conducted with HST and Chandra and comment on particle acceleration and main emission processes. We further use the data to investigate the observed 3-dimensional structure of the jet and the magnetic field structure.

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106.12 – Revealing the Evolving Accretion Disk Corona in AGNs with Multi-Epoch X-ray Spectroscopy: the case of Mrk 335

Active galactic nuclei host an accretion disk with an X-ray producing corona around a supermassive black hole. In bright sources, such as the Seyfert 1 galaxy Mrk 335, reflection of the coronal emission off the accretion disk has been observed. Reflection produces numerous spectral features, such as the Fe Kα emission line and absorption edge, which allow various properties of the inner accretion disk and corona to be constrained. We perform a multi-epoch spectral analysis of a dozen *XMM-Newton*, *Suzaku*, and *NuSTAR* observations of Mrk 335, and optimize the fitting procedure to unveil correlations between the Eddington ratio and multiple spectral parameters. We find that the ionization parameter of the accretion disk correlates strongly with the Eddington ratio: the inner disk is more strongly ionized at higher flux. Interestingly, the slope of the correlation is less steep than previously predicted. Furthermore, the cut-off of the power-law spectrum increases in energy with the Eddington ratio, whereas the reflection fraction exhibits a decrease. We interpret this behaviour as geometrical changes of the corona as a function of the accretion rate. Below ~10% of the Eddington limit, the compact and optically thick corona is located close to the inner disk, whereas at higher accretion rates the corona is likely optically thin and extends vertically further away from the disk surface. Compared to previous work that considered individual spectra, we find that multi-epoch spectroscopy is essential for breaking degeneracies in the spectral fits and for obtaining accurate spectral parameters. Furthermore, we show that this method provides a powerful tool to study coronal evolution. The rich archives of *XMM-Newton*, *Suzaku*, and *NuSTAR* provide the opportunity to extend this investigation to include several other bright AGN, which will reveal whether the behaviour that we found is common or unique to Mrk 335.

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106.13 – Constraining Properties of AGN Coronae with NuSTAR: the Case of the Obscured Seyfert 1.9 Nucleus MCG -05-23-016

Robust measurements of the high-energy cut-off in the coronal continuum of AGN have long been limited to a small set of the brightest examples and almost exclusively to unobscured nuclei. We report on a direct measurement of the cut-off energy in the nuclear continuum of the obscured Seyfert 1.9 nucleus MCG-05-23-016 with unprecedented precision. The high sensitivity of NuSTAR in the hard X-ray band allows us to clearly disentangle the spectral curvature of the primary continuum from that of the reprocessed component. Using a simple phenomenological spectral model, we measured the cut-off energy to be 116+/-6 keV, while more complex Comptonization models provided independent constraints on the kinetic temperature of the electrons in the corona and its optical depth. Similar to a number of such measurements perfomed with NuSTAR in the past few years, and consistent with analyses of relatively large samples of hard X-ray spectra from the NuSTAR survey of nearby AGN, the optical depth was found to be of order unity for a range of assumed simple geometries. This means that the data are pushing the currently available models to the limits of their validity. In combination with the observations of spectral signatures from the innermost region of the accretion disk, and the observed variability of the high-energy cut-off, these results allow us to constrain the spatial extent of the AGN corona, its inhomogeneity and physical conditions needed to maintain its structure.

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106.14 – Probing Turbulence and Acceleration at Relativistic Shocks in Blazar Jets

Acceleration at relativistic shocks is likely to be important in various astrophysical jet sources, including blazars and other radio-loud active galaxies. An important recent development for blazar science is the ability of Fermi-LAT data to pin down the power-law index of the high energy portion of emission in these sources, and therefore also the index of the underlying non-thermal particle population. This paper highlights how multiwavelength spectra including X-ray band and Fermi data can be used to probe diffusive acceleration in relativistic, oblique, MHD shocks in blazar jets. The spectral index of the non-thermal particle distributions resulting from Monte Carlo simulations of shock acceleration, and the fraction of thermal particles accelerated to non-thermal energies, depend sensitively on the particles' mean free path scale, and also on the mean magnetic field obliquity to the shock normal. We investigate the radiative synchrotron/Compton signatures of thermal and non-thermal particle distributions generated from the acceleration simulations. Important constraints on the frequency of particle scattering and the level of field turbulence are identified for the jet sources Mrk 501, AO 0235+164 and Bl Lacertae. Results suggest the interpretation that turbulence levels decline with remoteness from jet shocks, with a significant role for non-gyroresonant diffusion.

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106.15 – GeV Blazar flares several parsecs from the central engine. Who pays the seed photon bill?

In Blazars, multi-wavelength observations suggest that some GeV flares take place at the location of the mm VLBI core, several pc from the black hole. This location for the GeV emission requires a yet un-identified source of seed photons to be Inverse Compton scattered to GeV energies. Our model for these flares involves a fast spine and slow sheath configuration for the relativistic jet, where the mildly beamed sheath emission will illuminate with a large opening angle the outer regions of the Molecular Torus. The heated clouds will then radiate and their emission will be relativistically boosted in the spine frame where it can they be up-scattered to GeV energies. We argue, through analytical work and simulations, that this can be the seed photon source that produces the GeV flares.

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106.16 – Soft X-ray Excess from Hot GRMHD Accretion in AGNs

In an attempt to better understand a fundamental physics behind the so called “soft X-ray excess (SE)” often observed in many Seyfert AGNs, we propose a novel model where the innermost accreting plasma, most likely originating from the ISCO of a standard accretion disk around a black hole, could develop into a fast MHD shock under strong gravity efficiently producing relativistic electrons in the downstream region. These energetic particles then Compton up-scatter incoming EUV disk photons to characterize the SE feature in AGN spectra. In this preliminary calculation we find that the characteristics of the modeled SE depends only on shocked electron temperature (kTe), inner disk temperature (kTin), inclination (theta) and BH spin (a). As a case study we demonstrate that the model is successful in describing the observed SE in Ark120 implying that the Comptonizing downstream region is very compact (~2-3 gravitational radii) resembling the putative X-ray “hot coronae”. The best-fit analyses suggest that kTe varies from 60keV to 140keV depending on BH spin all with small inclination angles (~20-40deg).

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106.17 – Uncovering Nature’s 100 TeV Particle Accelerators in the Large-Scale Jets of Quasars

Since the first jet X-ray detections sixteen years ago the adopted paradigm for the X-ray emission has been the IC/CMB model that requires highly relativistic (Lorentz factors of 10-20), extremely powerful (sometimes super-Eddington) kpc scale jets. R I will discuss recently obtained strong evidence, from two different avenues, IR to optical polarimetry for PKS 1136-135 and gamma-ray observations for 3C 273 and PKS 0637-752, ruling out the EC/CMB model. Our work constrains the jet Lorentz factors to less than ~few, and leaves as the only reasonable alternative synchrotron emission from ~100 TeV jet electrons, accelerated hundreds of kpc away from the central engine. This refutes over a decade of work on the jet X-ray emission mechanism and overall energetics and, if confirmed in more sources, it will constitute a paradigm shift in our understanding of powerful large scale jets and their role in the universe. Two important findings emerging from our work will also discussed be: (i) the solid angle-integrated luminosity of the large scale jet is comparable to that of the jet core, contrary to the current belief that the core is the dominant jet radiative outlet and (ii) the large scale jets are the main source of TeV photon in the universe, something potentially important, as TeV photons have been suggested to heat up the intergalactic medium and reduce the number of dwarf galaxies formed.

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106.18 – *NuSTAR* Observations of Reddened Quasars

Reddened quasars selected from the FIRST and 2MASS surveys appear to be in a transitional link in the merger-induced black hole growth/galaxy evolution model. We present the *NuSTAR* and *XMM-Newton/Chandra* observations of 2 FIRST-2MASS red quasars, F2M 0830+3759 and F2M 1227+3214. The combination of broad-band X-ray coverage and physically-motivated spectral models allow us to characterize the X-ray obscuration in these systems. We find that much heavier obscuration is present globally than along the line-of-sight for F2M 0830+3759, and that F2M 1227+3214 may also have much higher amounts of global versus line-of-sight obscuration. These results are consistent with the paradigm that red quasars are evacuating their heavy cocoon of dust and gas, unveiling the central nucleus while higher column densities of gas are present globally, playing a role in reprocessing the intrinsic emission.

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106.19 – Decoding the spectral variations in the bare Seyfert 1 galaxy Fairall 9

X-ray spectroscopy and variability are powerful tools to understand the fundamental physics and accretion processes occurring in active galactic nuclei. The analysis is often hampered by the wealth of processes occurring simultaneously, making them difficult to disentangle. Our talk focuses on the luminous Seyfert 1 galaxy Fairall 9, whose spectrum and timing behavior is much simpler, as it is not affected by absorption processes. We aim to present a comprehensive spectral and timing study, based on an observing campaign performed in 2014. It consisted of a long-term Swift monitoring, three pointed XMM observations and one NUSTAR observation, performed jointly with one of XMM pointings. The different flux states of the pointed XMM observations allow us to identify the continuum as the main variability driver and constrain the accretion disk parameters with unprecedented quality. We are also able to establish that the source geometry remained absolutely unchanged over several months, a behavior not seen in other AGN. We study the connection of the UV and X-ray emission from the long-term Swift monitoring and establish that the UV lags the X-rays by several days. These time lags are then compared, together with the UV rms spectrum, to what is expected for a standard thin accretion disk and put into context of the results from the analysis of the XMM and NuSTAR data. Taken together this will provide us with the most complete picture of this AGN yet.

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106.20 – The Gamma-Ray Blazar Quest: state of the art and future perspectives

In 2011 we discovered that gamma-ray blazars detected by Fermi show extremely peculiar infrared colors. On the basis of this discovery we developed a procedure that allowed us to recognize gamma-ray blazar candidates within the sources associated in the Fermi catalogs with an uncertain classification. We also built a method to search for blazar-like sources as potential counterpart of the unidentified gamma-ray sources (UGSs). However, to confirm the real nature of the selected candidates, optical spectroscopy is necessary. Thus, we started an optical spectroscopic campaign to observe the selected gamma-ray blazar candidates and unveil their origin. In this work we present the state-of-art of our observational campaign that allowed us to discover previously unknown gamma-ray blazars and a review of the results achieved to date. Future perspectives of our observing strategy developed to "resolve the gamma-ray sky`` having all Fermi objects associated will be also discussed.

Author(s): Francesco Massaro[6], Nuria Alvarez Crespo[6], Raffaele D'Abrusco[4], Marco Landoni[1], Nicola Masetti[2], Federica Ricci[5], Dan Milisavljevic[3], Alessandro Paggi[3], Howard Alan Smith[3]
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106.22 – Evolution of Global Relativistic Jets: Collimations and Expansion with kKHI and the Weibel Instability

In the study of relativistic jets one of the key open questions is their interaction with the environment. Here, we study the initial evolution of both electron-proton (e^-- p^+) and electron-positron ($e^\pm$) relativistic jets, focusing on their lateral interaction with ambient plasma. We follow the evolution of toroidal magnetic fields generated by both the kinetic Kelvin-Helmholtz (kKH) and Mushroom instabilities (MI). For an e^-- p^+ jet, the induced magnetic field collimates the jet and electrons are perpendicularly accelerated. As the instabilities saturate and subsequently weaken, the magnetic polarity switches from clockwise to counter-clockwise in the middle of the jet. For an $e^\pm$ jet, we find strong mixing of electrons and positrons with the ambient plasma, resulting in the creation of a bow shock. The merging of current filaments generates density inhomogeneities which initiate a forward shock. Strong jet-ambient plasma mixing prevents a full development of the jet (on the scale studied), revealing evidence for both jet collimation and particle acceleration in the forming bow shock. Differences in the magnetic field structure generated by e^-- p+ and $e^\pm$ jets may contribute to the polarization properties of the observed emission in AGN jets and gamma ray bursts.

Author(s): Ken-Ichi Nishikawa[8], Jacob Trier Trier Frederiksen[6], Aake Nordlund[6], Yosuke Mizuno[2], Philip E. Hardee[11], Jacek Niemiec[4], Jose Gomez[3], Asaf Pe'er[10], Ioana Dutan[5], Athina Meli[12], Helene Sol[7], Martin Pohl[9], Dieter Hartmann[1]
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106.23 – The *NuSTAR* View of Reflecting and Absorbing Circumnuclear Material in AGN

The physical conditions and precise geometry of the accreting circumnuclear material in the vicinity of supermassive black holes remain open and critical questions. Between July 2012 and February 2013, *NuSTAR* and *XMM-Newton* performed four long-look joint observations of the type 1.8 Seyfert, NGC 1365. We have analyzed the variable absorption seen in these observations in order to characterize the geometry of the absorbing material. Two of the observations caught NGC 1365 in an unusually low absorption state, revealing complexity in the multi-layer absorbers which had previously been hidden, including a the Compton-thick torus, BLR clouds, and a patchy absorber with a variable column around 10^{22} cm^{-2} and a line of sight covering fraction of 0.3–0.9 which responds directly to the intrinsic source flux, possibly due to a wind geometry. We have also analyzed two *NuSTAR* observations of NGC 7582, a well-studied X-ray bright Seyfert 2 with moderately heavy highly variable absorption and strong reflection spectral features. Changes in the spectral shape and high reflection fractions have led to competing explanations: 1) the central X-ray source partially "shut off", decreasing in intrinsic luminosity, with a delayed decrease in reflection features due to the light-crossing time of the Compton-thick material or 2) the source became more heavily obscured, with only a portion of the power law continuum leaking through. The high quality of the *NuSTAR* spectra above 10 keV give us the best look at the reflection hump to date and allow us to test these two scenarios.

Author(s): Elizabeth Rivers[1]
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106.24 – The Extremes of Quasar Variability

Variability is one of the key observational properties of quasars, and it can be used as a probe of their fueling, physics, and evolution. A new generation of synoptic sky surveys, in combination with the novel data analytics tools, offers unprecedented data sets for the studies of quasars in the time domain. I will illustrate this with examples from the Catalina Real-Time Transient Survey (CRTS), which has an open and growing archive of 500 million light curves, including 350,000 spectroscopically confirmed quasars, with the time baselines ranging from 10 minutes to 10 years. I will discuss a new approach to discover quasars using a combination of variability and mid-IR colors from WISE, which results in a catalog of over a million quasar candidates. I will then discuss quasars with extreme, anomolous light curves, including quasars that have gone through extreme brightening events over the past decade with concordant large changes in their spectroscopic properties. I will also discuss a small subset of quasars with periodic light curves which we interpret as a signature of close (milliparsec scale) supermassive black hole (SMBH) binaries.

Author(s): Daniel Stern[1]
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106.25 – Swift multi-wavelength observations of the high-redshift Blazar S5 0836+710 (4C 71.07)

We present the preliminary results of a year-long Swift monitoring campaign of the high-redshift (z=2.172) flat-spectrum radio quasar (FSRQ) S5 0836+710 (4C 71.07). The campaign, based on one observation per month, 5 ks each observation, for 12 months, allowed us to investigate the synchrotron and nuclear emission contributions to the optical-UV frequency range of its spectral energy distribution and the X-ray spectral variations along a baseline of a year. We obtained a high-accuracy determination of UVOT magnitudes, an X-ray photon index with an uncertainty of the order of 5%, and well-sampled light curves both in the optical-UV and X-ray energy bands to study their possible modulations and correlations. Our study allowed us to exploit the unique Swift capabilities in terms of both simultaneous energy coverage and schedule flexibility. The Swift monitoring campaign was supported by observations by the GLAST-AGILE Support Program (GASP) of the Whole Earth Blazar Telescope (WEBT) Collaboration, which provided radio, near-infrared, and optical photometric data as well as optical polarimetry. Moreover, a spectroscopic monitoring was obtained at the William Herschel Telescope (WHT) and the Nordic Optical Telescope (NOT). All these observations will allow us to obtain a comprehensive picture of the jet as well as of the nuclear source emission.

Author(s): Stefano Vercellone[2], Patrizia Romano[2], Claudia Maria Raiteri3, Jose Acosta Pulido[1], Massimo Villata3, Maria Isabel Carnerero Martin3
Institution(s): *1. IAC, 2. INAF-IASF Palermo, 3. INAF-OATO*

106.26 – X-ray and gamma-ray polarization signatures of 3D multi-zone time-dependent hadronic model of blazar emission

The origin of the high-energy spectral component of blazar emission is still controversial. Polarization signatures can provide additional diagnostics on the leptonic and the hadronic models. We have developed a 3D multi-zone, time-dependent hadronic model based on Fokker-Planck equations. Coupled with a polarization-dependent radiation transfer code 3DPol, we derive the snap-shot spectral energy distributions and frequency-dependent polarization signatures, as well as multi-wavelength light curves and polarization variations. These findings can be confronted with future high-energy polarization observations to distinguish between the leptonic and the hadronic models.

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106.27 – The Extreme Gravitationally Redshifted Fe-line constraining the Rotation of the Super-Massive Black Hole in Mrk 876

Most galaxies undergo one or more eras of Active Galactic Nucleus (AGN) activity throughout their existence. During this era their environment, under the influence of gravity due to the central super-massive black hole, emits from X-ray to soft gamma-ray energies. Therefore these spectra and their features carry information on the extreme gravitational conditions that describe the super-massive black hole. However these spectral features can be transient and shifted to unexpected energies making their detection difficult. Consequently, properties of the super-massive black hole can go undetected.
We present our recent results of a case study on the AGN Mrk 876. The detection of a transient and extreme gravitationally redshifted Fe-line feature in the X-ray spectrum allows us to find its emission mechanism, thereby constraining the rotation of the super-massive black hole in the center of Mrk 876. This finding together with a morphological study of the source might give a consistent picture on the evolution of AGN.

Author(s): Eugenio Bottacini[1]
Institution(s): *1. Stanford*

106.28 – Interpreting Sgr A*'s Most Luminous X-ray Flares

During ambitious X-ray and radio monitoring campaigns with *Chandra*, *XMM*, *Swift*, and the VLA, we have detected the brightest-ever X-ray flares from Sgr A*. These flares likely probe the physical processes and accretion flow near the black hole's event horizon. Yet, despite years of observational and theoretical study, we do not have a complete, unique model to explain these high-energy flares, or their relationship to variability at other wavelengths. Viable models range from the tidal disruption of asteroids to collimated outflows to magnetic reconnection, motivating observers to place tighter constraints on the timing and multiwavelength properties of these outbursts. X-ray flares may also help us relate Sgr A* to weakly accreting black holes across the mass spectrum. I will discuss the possible origins and continuing mysteries surrounding Sgr A*'s high-energy flares and give a brief update on the Sgr A*/G2 interaction.

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106.29 – Particle acceleration from an inner accretion disc into compact corona and further out: case of an organised magnetic field near a supermassive black hole

Upcoming observational techniques in X-rays and millimeter spectral bands will allow to probe the inner corona of accretion discs near supermassive black holes. Size of this region only a few

gravitational radii has been inferred from various circumstantial evidence. To populate ithe region with particles, pair-creation in ergosphere and transport of particles via accretion have been invoked.
Electromagnetic fields are a likely agent of acceleration in strong gravity of a rotating black hole. We put forward a scenario with an organised component of the magnetic field near a supermassive black hole. An emergent flow of particles may be induced in a preferentially bi-polar direction. Our mechanism does not seem to be capable of producing ultra-high energy cosmic rays but it does expel particles along unbound trajectories.
The mentioned concept is relevant also from a purely theoretical viewpoint of dynamical properties of particle motion in General Relativity, namely, the onset of chaos near a black hole. We conclude that the role of black-hole spin in setting the chaos is more complicated than initially thought (based on http://arxiv.org /abs/1408.2452).

Author(s): Vladimir Karas[1], Ondrej Kopacek[1], Devaky Kunneriath[1], Jiri Kovar[2], Petr Slany[2]
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106.30 – PKS 1510-089: Fifteen years of X-ray Monitoring

The blazar PKS 1510-089 is one of the best-monitored of all blazars, due to near-continuous monitoring by the RXTE and SWIFT satellites at weekly or better intervals. The RXTE data, in particular, provide a well-sampled (~twice per week for 10 months per year) 3-color (2-4 keV, 4-7 keV and 7-10 keV) light curve spanning from 1996 to 2011. SWIFT data both overlap with the RXTE data stream and extend it up through the present day. The resulting light-curve gives us an excellent tool to correlate with Fermi observations. Both Fermi and SWIFT have observed the source from 2008 to 2015. We will present an analysis of the light curve, including a search for orphan flares (i.e., flares observed in only a single band), one of which was detected in early 2009 in PKS 1510-089 by Marscher et al. (2010). Cross-correlation of multi-wavelength light curves and studies of orphan flares could provide insight into leptonic and hadronic blazar emission models.

Author(s): Evan Smith[1], Eric S. Perlman[1], Jamie Holder[1]
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106.31 – A Study of the X-ray Periodicities in the Remarkable Transient Source Swift J1644+57

Swift J1644+57 was discovered when it exhibited bright X-ray activity that was believed to be triggered from the infall of a tidally disrupted star near a massive black hole. The observation of a tidal disruption event (TDE) can provide clues to the geometry and physics near the black hole. If a jet forms, as we think happened with Swift J1644+57, it can provide data to study jet creation and the density of matter in a possible accretion disc. We have analyzed Swift X-ray Telescope (XRT) observations of Swift J1644+57 from initial onset to 502 days after TDE onset. We used a Z-transform Discrete Correlation Function (ZDCF) to search for periodicities in the Swift X-ray light curve. We analyzed the X-ray light curve in five time regions, including 0 to 4.5 days after TDE onset, 4.5 to 55 days after TDE onset, 55 to 104 days after TDE onset, 104 to 145 days after TDE onset, and 145 to 502 days after TDE onset. After implementing red and white noise reduction modeling to our ZDCF analysis, we found plausible detections of periodicities. We briefly discuss implications of these periods on the geometry and feeding of the tidal disruption event.

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106.32 – Time-Dependence of VHE Gamma-Ray induced Pair Cascades in Radio Galaxies

Recently, several intermediate frequency peaked BL Lac objects (IBL), low frequency peaked BL Lac objects (LBL) and flat spectrum radio quasars (FSRQ) were detected as very high energy (VHE, $E > 100$ ~ GeV) γ-ray sources. These discoveries suggest that γγ absorption and pair cascades might occur in those objects, leading to excess γ-ray emission which may be observable also in off-axis viewing directions (i.e., like in radio galaxies) when deflected by moderately strong magnetic fields. Here, we investigate the time dependence of the Compton γ-ray emission from such VHE γ-ray induced pair cascades. We show that the cascade emission is variable on time scales much shorter than the light-crossing time across the characteristic extent of the external radiation field, depending on the viewing angle and γ-ray energy. Thus, we find that the cascade Compton interpretation for the *Fermi* γ-ray emission from radio galaxies is still consistent with the day-scale variability detected in the *Fermi* γ-ray emission of radio galaxies, such as NGC 1275, which we use as a specific example.

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106.33 – Swift/BAT and MAXI/GSC broadband transient monitor

"Time-domain astronomy" is one of the frontier field of astronomy for the next decade. Since the most of the transient sources show the temporal variation in a broad spectral range, it would be ideal to have the real time transient monitor which covers a wide energy band. We present the newly developed broadband transient monitor using the Swift Burst Alert Telescope (BAT) and the MAXI Gas Slit Camera (GSC) data. Our broadband transient monitor monitors high-energy transient sources from 2 keV to 200 keV in seven energy bands by combining the BAT (15–200keV) and the GSC (2–20keV) data. Currently, daily and 90-minute (one orbit) averaged light curves are available for 106 high-energy transient sources. Our broadband transient monitor is available to the public through our web server, http://yoshidalab.mydns.jp /bat_gsc_trans_mon/, for wider use by the community. We discuss the daily sensitivity of our monitor and possible future improvements to our pipeline.

Author(s): Takanori Sakamoto[1], Ryoma Oda[1], Tatehiro Mihara4, Atsumasa Yoshida[1], Makoto Arimoto5, Scott Douglas Barthelmy3, Nobuyuki Kawai5, Hans A. Krimm3, Satoshi Nakahira[2], Motoko Serino4
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107 – Astroparticles, Cosmic Rays, and Neutrinos Poster Session

107.01 – Observational Study on Connection between Sprites and TGFs with GRT-WF

Although it is known that terrestrial gamma-ray flashes (TGFs) can be caused by the electron-cosmic ray Bremsstrahlung in the presence of the Earth magnetic field, the acceleration process of electrons in the Earth atmosphere is not clearly understood. On the other hand, electrons inside thunderclouds produce lightnings (under the clouds) as well as sprites (above the clouds). We study the connection between sprites and TGFs since both of them require free atmospheric electrons. We constructed Goddard Robotic Telescope - Wide Field (GRT-WF) in June 2011, which is composed of seven wide field optical camera located at Florida Gulf Coast University (FGCU), to observe sprites in all the sky. We have recorded about 600 sprites so far, and studied possible associations with TGFs detected by NASA's Fermi/GBM and RHESSI. The location of GRT-WF has been chosen because the area is one of the highest TGF detection regions by Fermi/GBM (others are Africa and South-East Asia).

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107.02 – Cosmic rays and their modulation in the heliosphere by studying gamma rays from the Sun with Fermi-LAT: updated models

The Sun is a known quiescent gamma-ray source. Its gamma-ray steady-state, characterized by two distinct emissions, is unique for its spatially and spectrally distinct components: 1) disc emission due by pion decay of CR hadrons interacting with the solar atmosphere; 2) spatially extended emission from inverse Compton (IC) scattering of CR electrons on the solar photons of the heliosphere. Being produced by CRs, which are affected by solar modulation, the intensity of both emissions is expected to be inversely proportional to the solar activity. After the discovery of the quiet solar emission with EGRET, thanks to the high sensitivity of Fermi-LAT we can now monitor the solar steady-state in the various periods of solar activity. The release of Pass 8 data, with its improved event reconstruction and larger effective area, provides a unique opportunity to refine the study and extend it to different solar activities and also to lower and higher energies. In fact a first study was conducted using 18 month of data during low solar activity, where the best model for IC emission was investigated. Now the recent CR electron and positron measurements by Pamela, AMS-02, Fermi, and the changed solar activity call for a more extended analysis. We present here updates on solar IC models based on available CR measurements for different solar activity.

Author(s): Elena Orlando3, Nicola Giglietto[1], Igor V Moskalenko3, Silvia Raino'[1], Andrew Strong[2]
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107.03 – A multi-messenger search for the origin of high-energy astrophysical neutrinos with VERITAS and Fermi

The astrophysical flux of TeV-PeV neutrinos discovered by the IceCube observatory is likely to originate in hadronic interactions at or near cosmic-ray accelerators. While no point-sources of neutrinos have been identified so far, it may be possible to detect them indirectly by searching for the emission of pion-decay gamma rays produced in such interactions. The sensitivity of present gamma-ray instruments, such as the Fermi space telescope and the VERITAS air Cherenkov telescope array, can be used to search for a GeV-TeV gamma-ray signature from the neutrino directions. We present preliminary results from 2 years of VERITAS observations of muon-neutrino event positions detected by IceCube and discuss current plans to implement prompt follow-up observations of these events. We also report on the analysis of Fermi-LAT data for these events which enhances the sensitivity of this search to fast transient sources.

Author(s): Marcos Santander[1]
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107.04 – Galactic synchrotron radiation from radio to microwaves, and its relation to cosmic-ray propagation models: past, present and future

Galactic synchrotron radiation observed from radio to microwaves is produced by cosmic-ray (CR) electrons propagating in magnetic fields (B-fields). The low-frequency foreground component separated maps by WMAP and Planck depend on the assumed synchrotron spectrum. The synchrotron spectrum varies for different line of sights as a result of changes on the CR spectrum due to propagation effects and source distributions. Our present knowledge of the CR spectrum at different locations in the Galaxy is not sufficient to distinguish various possibilities in the modeling. As a consequence uncertainties on synchrotron emission models complicate the foreground component separation analysis with Planck and future microwave telescopes. Hence, any advancement in synchrotron modeling is important for separating the different foreground components.
The first step towards a more comprehensive understanding of degeneracy and correlation among the synchrotron model parameters is outlined in our Strong et al. 2011 and Orlando et al. 2013 papers. In the latter the conclusion was that CR spectrum, propagation models, B-fields, and foreground component separation analysis need to be studied simultaneously in order to properly obtain and interpret the synchrotron foreground. Indeed for the officially released Planck maps, we use only the best spectral model from our above paper for the component separation analysis.
Here we present a collections of our latest results on synchrotron, CRs and B-fields in the context of CR propagation, showing also our recent work on B-fields within the Planck Collaboration. We underline also the importance of using the constraints on CRs that we obtain from gamma ray observations. Methods and perspectives for further studies on the synchrotron foreground will be addressed.

Author(s): Elena Orlando[1]
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108 – Cosmic Backgrounds and Deep Surveys Poster Session

108.01 – Clustering, Cosmology and a New Era of Black Hole Demographics: The Conditional Luminosity Function of AGNs

Deep X-ray surveys have provided a comprehensive and largely unbiased view of AGN evolution stretching back to z~5. However, it has been challenging to use the survey results to connect this evolution to the cosmological environment that AGNs inhabit. Exploring this connection will be crucial to understanding the triggering mechanisms of AGNs and how these processes manifest in observations at all wavelengths. In anticipation of upcoming wide-field X-ray surveys that will allow quantitative analysis of AGN environments, we present a method to observationally constrain the Conditional Luminosity Function (CLF) of AGNs at a specific z. Once measured, the CLF allows the calculation of the AGN bias, mean dark matter halo mass, AGN lifetime, halo occupation number, and AGN correlation function – all as a function of luminosity. The CLF can be constrained using a measurement of the X-ray luminosity function and the correlation length at different luminosities. The method is demonstrated at z ≈0 and 0.9, and clear luminosity dependence in the AGN bias and mean halo mass is predicted at both z. The results support the idea that there are at least two different modes of AGN triggering: one, at high luminosity, that only occurs in high mass, highly biased haloes, and one that can occur over a wide range of halo masses and leads to luminosities that are correlated with halo mass. This latter mode dominates at z<0.9. The CLFs for Type 2 and Type 1 AGNs are also constrained at z ≈0, and we find evidence that unobscured quasars are more likely to be found in higher mass halos than obscured quasars. Thus, the AGN unification model seems to fail at quasar luminosities.

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108.02 – The cosmic mult-messenger background field

The cosmic star formation history associated with baryon flows within the large scale structure of the expanding Universe has many important consequences, such as cosmic chemical- and galaxy evolution. Stars and accreting compact objects subsequently produce light, from the radio band to the highest photon energies, and dust within galaxies reprocesses a significant fraction of this light into the IR region. The Universe creates a radiation background that adds to the relic field from the big bang, the CMB. In addition, Cosmic Rays are created on variouys scales, and interact with this diffuse radiation field, and neutrinos are added as well. A multi-messenger field is created whose evolution with redshift contains a tremendous amount of cosmological information. We discuss several aspects of this story, emphasizing the background in the HE regime and the neutrino sector, and disccus the use of gamma-ray sources as probes.

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109 – Galactic Black Holes Poster Session

109.01 – Multi-wavelength Observations of Fast Infrared Flares from V404 Cygni in 2015

We used the fast photometry mode of our new Canarias InfraRed Camera Experiment (CIRCE) on the 10.4-meter Gran Telescopio Canarias to observe V404 Cyg, a stellar mass black hole binary, on June 25, 2015 during its 2015 outburst. CIRCE provided 10Hz sampling in the Ks-band (2.2 microns) In addition, we obtained simultaneous multi wavelength data from our collaborators: three GHz radio bands from the AMI telescope and three optical/UV bands (u', g', r') from ULTRACAM on the William Herschel 4.2-meter telescope. We identify fast (1-second) IR flares with optical counterparts of varying strength/color, which we argue arise from a relativistic jet outflow. These observations provide important constraints on the emission processes and physical conditions in the jet forming region in V404 Cygni. We will discuss these results as well as their implications for relativistic jet formation around stellar-mass black holes.

Author(s): Stephen S. Eikenberry[2], Yigit Dallilar[2], Alan Garner[2], R. Deno Stelter[2], Poshak Gandhi[4], Vik Dhillon[3], Stuart Littlefair[3], Thomas Marsh[5], Rob P Fender[1], Kunal Mooley[1]
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109.02 – Reflection Spectroscopy of the Black Hole Binary XTE J1752-223 in the Bright Hard State

During its rise to maximum in 2009, XTE J1752-223 stalled for a full month in the bright hard state at about 30% of its peak (Eddington) luminosity. Along this extended period, 60 RXTE pointed observations showed the luminosity and hardness ratio of the source to be extraordinarily stable, resulting in a unique data set of exceptional quality. We combined all these 300 ks of RXTE data into a single PCA (3-45 keV) spectrum with 82 million counts and a single HEXTE spectrum (20-250 keV) with 10.4 million counts. Using our calibration tools PCACORR and HEXBCORR, we greatly enhanced the sensitivity of the detectors to faint spectral features, such as the Fe line and edge. Fitting the PCA+HEXTE spectrum using an advanced version of our reflection code, which includes a physical model of Comptonization, we constrained: the spin of the black hole (or alternatively the inner radius of the accretion disk); the inclination of the system; the ionization state and Fe abundance of the disk's atmosphere; and the temperature and optical depth of the corona. We compare these results with similar ones we reported earlier for GX 339-4 in the bright hard state. XTE J1752-223 and GX 339-4 are the first two of 29 black hole binaries we propose to study using recalibrated RXTE archival data and our reflection models.

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109.03 – Photoionization modeling of GRO 1655-40: A scaled down AGN Warm Absrobers!

We present photoinization models of the absorption features Galactic X-ray Binary (XRB) by implementing the MHD accretion disk wind models employed to account for the ionization properties of the AGN Warm Absorbers (WA)(Fukumura et a. 2010). The implementation of the same models rests on the fact that the radial density profiles of these winds, n(r)~1/r, guarantees the correct values of the hydrogen equivalent column N_H of the most important ionic species at the correct values of their ionization parameter ξ and velocity v. The similarity of the winds' ionization properties is broken only by the peak frequency of the ionizing SED, which is in the UV in AGN and in X-rays in XRBs. This difference implies that the inner regions of the XRB winds are far more ionized than those of AGN, resulting in much smaller velocities for the same ionic species (e.g. Fe XXV) in XRB (v~1,000 km/s) than in AGN (v~10,000 km/s), in agreement with observation. Estimates of the wind mass flux deduced from our photonization modeling, imply that the latter is much larger than that needed to power the observed X-ray emission, a property that appears to be generic from the Galactic to the AGN black hole mass range suggesting a common underlying structure.

Author(s): Demosthenes Kazanas[2], Keigo Fukumura[1], Chris R. Shrader[2], Ehud Behar[3], Francesco Tombesi[4]
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109.04 – No Disk Winds in Failed Black Hole Outbursts? New Observations of H1743-322

The rich and complex physics of stellar-mass black holes in outburst is often referred to as the "disk-jet connection," a term that encapsulates the evolution of accretion disks over several orders of magnitude in Eddington ratio; through Compton scattering, reflection, and thermal emission; as they produce steady compact jets, relativistic plasma ejections, and (from high spectral resolution revelations of the last 15 years) massive, ionized disk winds. It is well established that steady jets are associated with radiatively inefficient X-ray states, and that winds tend to appear during states with more luminous disks, but the underlying physical processes that govern these connections (and their changes during state transitions) are not fully understood. I will present a unique perspective on the disk-wind-jet connection based on new Chandra HETGS, NuSTAR, and JVLA observations of the black hole H1743-322. Rather than following the usual outburst track, the 2015 outburst of H1743 fizzled: the disk never appeared in X-rays, and the source remained spectrally hard for the entire ~100 days. Remarkably, we find no evidence for any accretion disk wind in our data, even though H1743-322 has produced winds at comparable hard X-ray luminosities. I will discuss the implications of this "failed outburst" for our picture of winds from black holes and the astrophysics that governs them.

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109.05 – A Super-Eddington, Compton-Thick Wind in GRO J1655-40?

During its 2005 outburst, GRO J1655-40 was observed at high spectral resolution with the Chandra HETGS, revealing a spectrum rich with blueshifted absorption lines of elements ranging from oxygen to nickel, including exotic metals like titanium and scandium. It has been argued that magnetic fields must be responsible for the dense accretion disk wind that produces these deep absorption lines. But questions about this outburst remain, because the presence of this exotic wind coincides with extremely soft and curved X-ray spectra, remarkable X-ray variability, and bright, unexpected optical/infrared emission that varies on the orbital period. I will argue that the unusual features of this "hypersoft state" are natural consequences of a super-Eddington Compton-thick wind from the disk.

Author(s): Joseph Neilsen[2], Farid Rahoui[1], Jeroen Homan[2], Michelle Buxton[3]
Institution(s): *1. ESO, 2. MIT Kavli Institute, 3. Yale*

109.06 – X-ray spectral analysis of the steady states of GRS 1915+105

Of the black hole binaries (BHBs) discovered thus far, GRS 1915+105 stands out as an exceptional source primarily due to its wild X-ray variability, the diversity of which has not been replicated in any other stellar-mass black hole. Although extreme variability is commonplace in its light-curve, about half of the observations of

GRS1915+105 show fairly steady X-ray intensity. We report on the X-ray spectral behavior within these steady observations. Our work is based on a vast RXTE/PCA data set obtained on GRS 1915+105 during the course of its entire mission and 10 years of radio data from the Ryle Telescope, which overlap the X-ray data. We find that the steady observations within the X-ray data set naturally separate into two regions in a color-color diagram, which we refer to as steady-soft and steady-hard. GRS 1915+105 displays significant curvature in the Comptonization component within the PCA band pass suggesting significantly heating from a hot disk present in all states. A new Comptonization model 'simplcut' was developed in order to model this curvature to best effect. A majority of the steady-soft observations display a roughly constant inner disk radius, remarkably reminiscent of canonical soft state black hole binaries. In contrast, the steady-hard observations display a growing disk truncation that is correlated to the mass accretion rate through the disk, which suggests a magnetically truncated disk. A comparison of X-ray model parameters to the canonical state definitions show that almost all steady-soft observations match the criteria of either thermal or steep power law state, while the thermal state observations dominate the constant radius branch. A large portion 80 % of the steady-hard observations matches the hard state criteria when the disk fraction constraint is neglected. These results combine to suggest that within the complexity of this source is a simpler underlying basis of states, which map to those observed in canonical BHBs.

Author(s): Charith Peris[1], Ronald A. Remillard[2], James F. Steiner[2], Saeqa Dil Vrtilek[1], Peggy Varniere[4], Jerome Rodriguez[4], Guy G Pooley[3]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. MIT, 3. University of Cambridge, 4. University of Paris*

109.07 – Modeling the thermal X-ray emission around the Galactic center from colliding stellar winds

The Galactic center is a hotbed of astrophysical activity. Powering these processes is the injection of wind material from ~30 massive Wolf-Rayet (WR) stars orbiting within 12" of the super-massive black hole (SMBH). Hydrodynamic simulations of such colliding and accreting winds produce a complex density and temperature structure of cold wind material shocking with the ambient medium, creating a large reservoir of hot, X-ray-emitting gas. A Chandra X-ray Visionary Program that observed the Galactic center for 3 Ms resolved this diffuse emission. This work computes the X-ray emission from these hydrodynamic simulations of the WR winds with the aim of reproducing the Chandra observations, amid exploring a variety of SMBH feedback mechanisms. The success of the model is the spectrum from the 2"-5" ring around the SMBH matches the shape of the observed spectrum very well. This naturally explains that the hot gas comes from colliding WR winds, and that the winds speeds of these stars are in general well constrained. The model flux in this ring and over the ±6" images of 4-9keV is ~2.2× lower than the observations, with stronger feedback mechanisms leading to weaker X-ray emission since more hot, X-ray-emitting gas is cleared from the spherical r < 12" simulation volume. Possible improvements to rectify this flux discrepancy are increasing the mass loss rates of the WRs and/or adding more gas into the simulation, such as from the O stars and their winds, so the adiabatic WR shocks occur closer to their stars, thereby becoming brighter in X-rays.

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109.08 – NuSTAR Observations of V404 Cygnus in Outburst

The Galactic LMXB V404 Cygnus, one of the closest known black hole binary systems, went through its first major outburst in ~25 years in summer 2015. Over the course of this event, the NuSTAR observatory played an active role in the substantial multi-wavelength campaign initiated, performing a series of exposures covering a span of several weeks. These observations revealed extreme variability on both long and short timescales, as well as complex broadband X-ray spectra. More recently, after having returned to quiescence, V404 Cygnus also exhibited an unexpected re-brightening only ~6 months later. In this talk I will present an overview of the NuSTAR campaign, and discuss some early results from these observations.

Author(s): Dom Walton[2], NuSTAR Collaboration[1]
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109.09 – X-ray flare properties of Sgr A*

Daily X-ray flaring represents an enigmatic phenomenon of Sgr A* --- the supermassive black hole at the center of our Galaxy. We report results from a systematic X-ray study of this phenomenon, based on extensive Chandra observations obtained from 1999 to 2012, totaling about 4.5 Ms. We detect flares, using a combination of the maximum likelihood and Markov Chain Monte Carlo methods, which allow for a direct accounting for the pile-up effect in the modeling of the flare lightcurves and an optimal use of the data, as well as the measurements of flare parameters, including their uncertainties. A total of 82 flares are detected. About one third of them are relatively faint, which were not detected previously. The observation-to-observation variation of the quiescent emission has an average root-mean-square of 6%-14%, including the Poisson statistical fluctuation of faint flares below our detection limits. We find no significant long-term variation in the quiescent emission and the flare rate over the 14 years. In particular, we see no evidence of changing quiescent emission and flare rate around the pericenter passage of the S2 star around 2002. We show clear evidence of a short-term clustering for the flares on time scale of 20-70 ks. We will also report new results on the spectral and lightcurve properties of the flares, as well as their fluence-duration relation after carefully accounting for the detection incompleteness and bias. Finally, we will use these results to constrain the origin and emission mechanism of the flares, which further helps to establish Sgr A* as a unique laboratory to understand the astrophysics of prevailing low-luminosity black holes in the Universe.

Author(s): Daniel Wang[1], Qiang Yuan[1]
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109.10 – High Energy Emission of V404 Cygni during 2015 outburst with INTEGRAL/SPI: Spectral analysis results, issues and solutions

A strong outburst of the X-ray transient V404 Cygni (= GS2023-338) was observed in 2015 June/July up to a level of 50 Crab in the hard X-ray domain.
We have used the INTEGRAL/SPI data to investigate the spectral behavior of the source between 20 and 1000 keV during its maximum of activity. We have found striking variability patterns at all timescales. For the 20-200 keV energy band, the huge signal to noise ratio allows us to scrutinize the source evolution on a never reached timescale (30 s). At higher energy, the spectral shape can be determined on a timescale < 1 h.
However, we note that at this level of photon flux, instrument's behavior may be severely tested and that some instrumental artifacts could affect the data analysis. We have performed thorough checks to ensure a correct handling of the SPI data and present how to obtain reliable spectral results on the emission of V404 Cyg. We demonstrate that, with the correct configuration, the hard X-ray emission, up to the MeV region, is well described by a two component model (Comptonisation law + cutoff power law) as observed in Cyg X-1 and for V404 Cygni itself at lower flux levels.

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110 – Galaxies and ISM Poster Session

110.02 – What dominates the X-ray emission of Andromeda at E>20 keV? New constraints from

NuSTAR and Swift on a very bright, hard X-ray source

Thanks to its better sensitivity and spatial resolution, NuSTAR allows us to investigate the E>10 keV properties of nearby galaxies. We now know that starburst galaxies, containing very young stellar populations, have X-ray spectra which drop quickly above 10 keV. We extend our investigation of hard X-ray properties to an older stellar population system, the bulge of M31. The NuSTAR and Swift simultaneous observations reveal a bright hard source dominating the M31 bulge above 20 keV, which is likely to be a counterpart of Swift J0042.6+4112 previously detected (but not classified) in the Swift BAT All-sky Hard X-ray Survey. This source had been classified as an XRB candidate in various Chandra and XMM-Newton studies; however, since it was not clear that it is the counterpart to the strong Swift J0042.6+4112 source at higher energies, the previous E < 10 keV observations did not generate much attention. The NuSTAR and Swift spectra of this source drop quickly at harder energies as observed in sources in starburst galaxies. The X-ray spectral properties of this source are very similar to those of an accreting pulsar; yet, we do not find a pulsation in the NuSTAR data. The existing deep HST images indicate no high mass donors at the location of this source, further suggesting that this source has an intermediate or low mass companion. The most likely scenario for the nature of this source is an X-ray pulsar with an intermediate/low mass companion similar to the Galactic Her X-1 system. We will also discuss other possibilities in more detail.

Author(s): Mihoko Yukita[1], Andrew Ptak3, Thomas J. Maccarone[6], Ann E. Hornschemeier3, Daniel R. Wik[1], Katja Pottschmidt3, Vallia Antoniou5, Frederick K. Baganoff[2], Bret Lehmer7, Andreas Zezas5, Patricia T. Boyd3, Jamie Kennea4, Kim L Page[8]
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110.03 – Global MHD simulations of cosmic ray driven galactic winds

Galactic outflows play an important role in galactic evolution. Despite their importance, a detailed understanding of the physical mechanisms responsible for the driving of these winds is lacking. In an effort to gain more insight into the nature of these flows, we perform global three-dimensional magneto-hydrodynamical simulations of an isolated starbursting galaxy. We focus on the dynamical role of cosmic rays injected by supernovae, and specifically on the impact of the streaming and anisotropic diffusion of cosmic rays along the magnetic fields. We find that these microphysical effects can have a significant effect on the wind launching and mass loading factors depending on the details of the plasma physics. Cosmic rays stream away from the densest regions near the galactic disk along partially ordered magnetic fields and, in the process, accelerate more tenuous gas away from the galaxy. For cosmic ray acceleration efficiencies broadly consistent with the observational constraints, cosmic rays are likely to have a notable impact on the wind launching.

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110.04 – Chandra Galaxy Atals - Global Hot Gas Properties

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. In our new project, the Chandra Galaxy Atlas, we systematically analyze the archival Chandra data of ~100 ETGs to study the hot ISM. Using uniformly derived data products with spatially resolved spectral information, we will present gas morphology, scaling relations and X-ray based mass profiles and address their implications.

Author(s): Dong-Woo Kim[2], Craig Anderson[2], Douglas J. Burke[2], Giuseppina Fabbiano[2], Antonella Fruscione[2], Jennifer L. Lauer[2], Michael L. McCollough[2], Douglas Morgan[2], Amy Mossman[2], Ewan O'Sullivan[2], Alessandro Paggi[2], Ginevra Trinchieri[1]
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110.05 – The Morphology of Nearby Ultraviolet Galaxy Halos

We have detected diffuse ultraviolet light around highly inclined galaxies within 100 Mpc, and around galaxies within 25 Mpc we can characterize its structure. The morphology of the diffuse light often corresponds to diffuse H-alpha and X-ray emission and is found above the central regions of galaxies as well as above regions with strong star formation. In some cases, brighter regions of diffuse ultraviolet light correspond to cold dust seen with Herschel. The most plausible explanation is that we are seeing extragalactic reflection nebulae, in which case the UV light traces the dust distribution and underlying star formation. The dust masses implied by the extragalactic flux are comparable to the dust in galaxy disks; if the dust-to-gas ratio is constant, then these galaxies expel about as much gas as they contain.

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

110.06 – X-ray Mass Profiles from Chandra Galaxy Atlas

We present preliminary results of a Chandra/XMM-Newton joint analysis on a sample of three Early Type Galaxies (ETGs, namely NGC4649, NGC4636 and NGC5846). X-ray observations of the hot ISM is used to measure the total enclosed mass assuming hydrostatic equilibrium, and compasion with mass distributions obtained through optical kinematics data of globular clusters and planetary nebulae yields informations about disturbances in the ISM distribution due to nuclear activity, merging history, etc. Our analysis makes use of the Chandra Galaxy Atlas (CGA) data products - exploiting the unmatched spatial resolution of the ACIS detectors to reveal fine ISM features and disturbances in the inner galactic regions - and XMM-Newton data - relying on the large field of view of EPIC detector to extend the mass profiles to larger radii. We then measured the mass profiles in various pie sectors to separate different gas features (e.g., discontinuity and extended tail) and compared them with GCs/PNe based mass profiles. The X-ray mass profiles of NGC4649 show a generally relaxed morphology and, in agreement with previous analysis, the comparison with the optical mass profiles shows a significant deviations on parsec scale likely due to non-thermal pressure linked to nuclear activity. In significantly disturbed cases (NGC4648 and NGC5846) where we found discontinuities and extended tails, we found that the mass profiles are over-estimated toward the compressed discontinuity and under-estimated toward the extended tails, similar to inflow and outflow cases. These preliminary results are promising toward an extended analysis of the whole CGA sample in order to study the distribution of gas temperature and metal abundances in the ISM, and to investigate scaling relations between ETG global quantities like ISM temperature, luminosity and total mass.

Author(s): Alessandro Paggi[2], Dong-Woo Kim[2], Craig Anderson[2], Douglas J. Burke[2], Giuseppina Fabbiano[2], Antonella Fruscione[2], Jennifer L. Lauer[2], Michael L. McCollough[2], Douglas Morgan[2], Amy Mossman[2], Ewan O'Sullivan[2], Ginevra Trinchieri[1]
Institution(s): *1. INAF-Osservatorio Astronomico di Brera, 2. Smithsonian Astrophysical Observatory*

110.08 – Search for Gamma-ray Emission from Dark Matter Annihilation in the Small Magellanic Cloud

with the Fermi Large Area Telescope

The Small Magellanic Cloud (SMC) is the second-largest satellite galaxy of the Milky Way and is only 60 kpc away. As a nearby, massive, and dense object with relatively low astrophysical backgrounds, it is a natural target for dark matter indirect detection searches. In this analysis, we use six years of Pass 8 data from the Fermi Large Area Telescope to search for gamma-ray signals of dark matter annihilation in the SMC. Using data-driven fits to the gamma-ray backgrounds, and a combination of cosmological N-body simulations and direct measurements of rotation curves to estimate the SMC dark matter density profile, we found that the SMC was well described by standard astrophysical sources, and no signal from dark matter annihilation was detected. We set conservative upper limits on the dark matter annihilation cross section. These constraints are in agreement with stronger constraints set by searches in the Large Magellanic Cloud and approach the canonical thermal relic cross section at dark matter masses lower than 10 GeV in the bb and $\tau^+\tau^-$ annihilation channels.

Author(s): Regina Caputo[6], Matthew Buckley[4], Pierrick Martin[1], Eric Charles[5], Alyson Brooks[4], Alex Drlica-Wagner[2], Jennifer Gaskins[3], Matthew Wood[5]
Institution(s): *1. CNRS, IRAP, 2. Fermi National Accelerator Laboratory, 3. GRAPPA, 4. Rutgers, 5. SLAC National Accelerator Laboratory, 6. University of California Santa Cruz*

110.09 – The Properties of Interstellar Dust From a Survey of X-ray Halos

Small-angle scattering of X-rays off interstellar dust grains produce X-ray halos around bright sources along absorbed lines of sight. While many studies have examined these halos, no systematic study has compared the available halo data to the large number of dust models that are commonly used. To address this, we have obtained the largest sample yet of X-ray halos from XMM-Newton and Chandra and fitted them with 14 dust grain models. We have also compared our results with the optical extinction, A_V, when it is available in the literature. Our results can be summarized as follows. (1) Comparing A_V with N_H values measured by X-ray spectral fitting, we find a ratio of A_V/N_H (10^{21} cm^{-2}) = 0.48 ± 0.06, similar to what has been found by previous workers. (2) Out of 35 halos, 27 could be fit by one or more grain models, with the most successful models having maximum grain radius a_{max} < 0.4 µm and fewer large grains than the less successful models. This suggests that the diffuse ISM does not contain a signicant presence of grains with a_{max} > 0.5 µm. (3) Most halos were best fit assuming a single dust cloud dominated the scattering, as opposed to smoothly distributed dust along the sight line. (4) Eight sources could not be fit with the models considered here; these tended to be distant (d > 5 kpc) sight lines through the Galactic thin disk. 5) Some sight lines had halos with observed X-ray scattering optical depth τ_{sca}/A_V that were significantly different than expected, which may be indicative of an inhomogeneous dust distribution across the halo extraction area on the sky.

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110.10 – The effects of dust scattering on high-resolution X-ray absorption edge structure

In high resolution X-ray spectroscopy, dust scattering significantly enhances the total extinction optical depth and alters the shape of photoelectric absorption edges. This effect is modulated by the dust grain size distribution, spatial location along the line of sight, and the imaging resolution of the X-ray telescope. We focus in particular on the Fe L-edge at 0.7 keV, fitting a template for the total extinction to the high resolution spectrum of three X-ray binaries from the Chandra archive: GX 9+9, XTE J1817-330, and Cyg X-1. In cases where dust is intrinsic to the source, a covering factor based on the angular extent of the dusty material must be applied to the extinction curve, regardless of imaging resolution. We discuss the various astrophysical cases in which scattering effects need to be taken into account.

Author(s): Lia Corrales[2], Javier Garcia[1], Joern Wilms[3], Frederick K. Baganoff[2]
Institution(s): *1. Harvard Center for Astrophysics, 2. MIT Kavli Institute for Astrophysics and Space Research, 3. University of Erlangen-Nuremberg*

110.11 – The Environment of Binary Nuetron Star Mergers

In addition to detections by LIGO, binary neutron star mergers may be detected via luminous interaction with surrounding interstellar media. Upcoming observations including the VLASS survey may be able to detect such interactions and offer constraints on the binary neutron star merger rate. In this talk, I will present the results of cosmological simulations of a cluster of galaxies followed down to redshift 0. Our calculation includes star formation from which we infer a supernova and binary neutron star production rate. Using pre-existing models of neutron star binaries, we follow the positions of neutron star pairs in the cluster potential throughout cosmic time allowing us to identify regions in which neutron stars merge. We present statistics of many Monte Carlo instances of nuetron star pairs and trajectories allowing us to constrain the approximate fraction of neutron stars merging in dense gas. Our work has implications for R-process enrichment of galaxies in addition to predicting electromagnetic counterparts to gravitational wave detections of neutron star mergers.

Author(s): Brandon Wiggins[1]
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110.12 – Investigating Metallicity Variations in Early-type Galaxies with Chandra

Some simulations of galaxy formation predict large variations in the metallicity of the hot X-ray emitting galaxy atmospheres, producing a higher-emission weighted metallicity than the true mass-weighted metallicity when a spectrum is fit. Since the variations may be detectable in existing data, we searched for the predicted variations using X-ray intensity maps from Chandra and color-color analysis, which can constrain the metallicity of an isothermal plasma. Applying this analysis to 5 early-type galaxies revealed variations in the surface brightness distribution but these variations are not simply due to changes in metallicity. NGC 5846 provides an important case study as the intensity of photons is high enough to fit spectra to small regions of the galaxy, providing a comparison to the results of the color-color analysis. Although the spectra of small regions in NGC 5846 are consistent with two temperature (2T) models, further analysis indicates that the metallicities and temperatures of the 2T models must fall within a certain range of the isothermal values predicted from color-color analysis. The contribution of undetected X-ray binaries to the diffuse X-rays were investigated, but they are likely not the cause of the variations.

Author(s): Patrick Dahlin[1], Edmund J. Hodges-Kluck[1], Joel N. Bregman[1]
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110.13 – Chandra Detection of X-ray Emission from Ultra-compact Dwarf Galaxies and Extended Star Clusters

We have conducted a systematic study of X-ray emission from ultra-compact dwarf (UCD) galaxies and extended star clusters (ESCs), based on archival Chandra observa- tions. Among a sample of 511 UCDs and ESCs complied from the literature, 17 X-ray counterparts with 0.5-8 keV luminosities above ~5 × 1036 erg s−1 are identified, which are distributed in eight early-type host galaxies. To facilitate comparison, we also identify X-ray counterparts of 360 globular clusters (GCs) distributed in four of the eight galaxies. The X-ray properties of the UCDs and ESCs are found to be broadly similar to those of the GCs. The incidence rate of X-ray-detected UCDs and ESCs, (3.3±0.8)%, while lower than that of the X-ray-detected GCs [(7.0±0.4)%], is substan- tially higher than expected from the field populations of external galaxies. A stacking analysis of the individually undetected UCDs/ESCs further reveals significant X-ray signals, which corresponds to an equivalent 0.5-8 keV luminosity of ~4 × 1035 erg s−1 per source. Taken together, these provide strong evidence that the X-ray emission from UCDs and ESCs is dominated by low-mass X-ray binaries having formed from stellar dynamical interactions, consistent with the stellar populations in these dense systems being predominantly old.

Author(s): Meicun Hou[1], Zhiyuan Li[1]
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110.14 – Where in the Milky Way is the North Polar Spur?

A series of pointed observations with XMM-Newton of the X-ray bright "North Polar Spur" (*) near l=30° and b=8° have been analyzed in combination with dedicated ground-based absorption measurements and three-dimensional reddening maps. There is compelling evidence that the southern terminus of the North Spur is absorption bounded and that the X-ray emitting region is behind the Aquila Rift clouds, at least hundreds of parsecs away. Moreover, absorbing columns deduced from X-ray spectral fitting correlate more tightly with dust optical depths from Planck than with any other ISM column indicator, suggesting that the emission may originate several kpc away. This result raises the question of a possible link between the Spur and outflows from the inner Galaxy (Fermi bubbles, Galactic wind).
(* Prop: 074189, P.I. K.D. Kuntz)

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111 – Galaxy Clusters Poster Session

111.03 – Observation of a nearby early merging cluster of galaxies, CIZA J1358.9-4750: new born shocks in the ICM

Cluster merger events drive shocks in the intra-cluster plasma and activate non-thermal phenomena such as particle acceleration, magnetic field amplification, and turbulence. However, details of these processes are not well known because of a lack of observations. The known examples of merging clusters are mostly in late merger phases, wherein the shocks have already reached the low-density outer regions. Therefore, finding nearby merging clusters in early phases, in which the shock is still located in dense regions, is of great importance.
In order to find suitable objects, we searched the CIZA catalog, which collects X-ray detected cluster candidates located behind the Zone of Avoidance, near the Galactic ridge. We found a very promising merging-cluster candidate CIZA J1358.9-4750, with a redshift of 0.07. It consists of a close pair of X-ray clusters of galaxies in North-west(NW) and South-east(SE), which are connected by an X-ray bright ``bridge” region in between. We observed this object with Suzaku and Chandra, and analyzed its archival short exposure XMM-Newton data. The Suzaku data revealed that the NW and SE clusters have temperatures of 5.2±0.2 keV and 4.6±0.2 keV, respectively. The bridge region was found to have a 1.6 times higher temperature, 9.2±1.5 keV. In the existing XMM-Newton data, we found an abrupt brightness jump coinciding in position with the Suzaku high-temperature region. With additional Chandra data, we found a bright plateau with a width of 2’, i.e. 170 kpc. The front and back jumps are presumably the forward and reverse shocks between the two clusters. Therefore, the object is likely to be a rather symmetric shock system, in which two clusters of similar masses are colliding. The Mach number of the collision was derived as 1.3±0.2 and 1.17±0.04 from the Suzaku temperature jump and the Chandra brightness jump, respectively. This Mach number and the X-ray temperature give the shock velocity as 1200 km/s. It can be combined with the separation of the two shocks(120 kpc), to yield an age estimate of 70 Myr after the shocks started to develop. Therefore, the system is indeed in a very early phase of its collision process.

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111.04 – The Merger Dynamics of Abell 2061

Abell 2061, a galaxy cluster at a redshift of z=.0784 in the Corona Borealis Supercluster, displays features in both the X-ray and radio indicative of merger activity. Observations by the GBT and the Westerbork Northern Sky Survey (WENSS) have indicated the presence of an extended, central radio halo/relic coincident with the cluster's main X-ray emission and a bright radio relic to the SW of the center of the cluster. Previous observations by ROSAT, Beppo-SAX, and Chandra show an elongated structure (referred to as the ‘Plume’), emitting in the soft X-ray and stretching to the NE of the cluster’s center. The Beppo-SAX and Chandra observations also suggest the presence of a hard X-ray shock slightly NE of the cluster’s center. Here we present the details of an August 2013 XMM-Newton observation of A2061 which has greater field of view and longer exposure (48.6 ks) than the previous Chandra observation. We present images displaying the cluster’s soft and hard X-ray emission and also a temperature map of the cluster. This temperature map highlights the presence of a previously unseen cool region of the cluster which we hypothesize to be the cool core of one of the subclusters involved in this merger. We also discuss the structural similarity of this cluster with a simulated high mass-ratio offset cluster merger taken from the Simulation Library of Astrophysical cluster Mergers (SLAM). This simulation would suggest that the Plume is gas from the cool core of a subcluster which is now falling back into the center of the cluster after initial core passage.

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111.06 – Early Results from Swift AGN and Cluster Survey

The Swift AGN and Cluster Survey (SACS) uses 125 deg^2 of Swift X-ray Telescope serendipitous fields with variable depths surrounding gamma-ray bursts to provide a medium depth (4 × 10^-15 erg cm^-2 s^-1) and area survey filling the gap between deep, narrow Chandra/XMM-Newton surveys and wide, shallow ROSAT surveys. Here, we present the first two papers in a series of publications for SACS. In the first paper, we introduce our method and catalog of 22,563 point sources and 442 extended sources. SACS provides excellent constraints on the AGN and cluster number counts at the bright end with negligible uncertainties due to cosmic variance, and these constraints are consistent with previous measurements. The depth and areal coverage of SACS is well suited for galaxy cluster surveys outside the local universe, reaching z > 1 for massive clusters. In the second paper, we use SDSS DR8 data to study the 203 extended SACS sources that are located within the SDSS footprint. We search for galaxy over-densities in 3-D space using SDSS galaxies and their photometric redshifts near the Swift galaxy cluster candidates. We find 103 Swift clusters with a > 3σ over-density. The remaining targets are potentially located at higher redshifts and require deeper optical follow-up observations for confirmations as galaxy clusters. We present a series of cluster properties including the redshift, BCG magnitude, BCG-to-X-ray center offset, optical richness, X-ray luminosity and red sequences. We compare the observed redshift distribution of the sample with a theoretical model, and find that our sample is complete for z ≤ 0.3 and 80% complete for z ≤ 0.4, consistent with the survey depth of SDSS. These analysis results suggest that our Swift cluster selection algorithm presented in our first paper has yielded a statistically well-defined cluster sample for further studying cluster evolution and cosmology. In the end, we will discuss our ongoing optical identification of z>0.5 cluster sample, using MDM, KPNO, CTIO, and Magellan data, and discuss SACS as a pilot for eROSITA deep surveys.

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111.07 – The Role of Outburst Shock Heating in AGN Feedback

One of the major discoveries of modern X-ray observatories is that central AGN in galaxies, groups, and clusters can regulate cooling in the diffuse X-ray emitting gas. This connection is demonstrated by the presence of large cavities in the diffuse gas, usually filled with radio-emitting plasma, that have been evacuated by jets from the AGN. This AGN feedback has important consequences for star formation, galaxy evolution, super-massive black hole growth, galaxy/black hole scaling relations, cluster scaling relations, and the growth of structure. Although it has generally been found that the kinetic output of central AGN scales with the gas cooling rate and is energetic enough to offset cooling, the details of how and where this energy is transferred to heat the gas are poorly understood. I will discuss the role of weak AGN outburst shocks in heating the diffuse gas, and present some results from a very deep (650 ks) Chandra observation of the galaxy group NGC 5813. With three three pairs of collinear cavities, each pair associated with an elliptical AGN outburst shock, NGC 5813 is uniquely well-suited to studying the outburst history of the AGN and the mean shock heating rate.

Author(s): Scott W. Randall[1], Paul Nulsen[1], Christine Jones[1], William R. Forman[1]
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111.08 – The AGN-driven shock in NGC 4472

Chandra observations of most cool core clusters of galaxies have revealed large cavities where the inflation of the jet-driven radio bubbles displace the cluster gas. In a few cases, outburst shocks, likely driven by cavity inflation, are detected in the ambient gas. AGN-driven shocks may be key to balancing the radiative losses as shocks will increase the entropy of, and thereby heat, the diffuse gas. We will present initial results on deep Chandra observations of the nearby (D=17 Mpc) early-type massive elliptical galaxy NGC 4472, the most optically luminous galaxy in the local Universe, lying on the outskirts of the Virgo cluster. The X-ray observations show clear cavities in the X-ray emission at the position of the radio lobes, and rings of enhanced X-ray emission just beyond the lobes. We will present results from our analysis to determine whether the lobes are inflating supersonically or are rising buoyantly. We will compare the energy and power of this AGN outburst with previous powerful radio outbursts in clusters and groups to determine whether this outburst lies on the same scaling relations or whether it represents a new category of outburst.

Author(s): Marie-Lou Gendron-Marsolais3, Ralph P. Kraft[1], Akos Bogdan[1], William R. Forman[1], Julie Hlavacek-Larrondo3, Christine Jones[1], Paul Nulsen[1], Scott W. Randall[1], Elke Roediger[2]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. University of Hull, 3. University of Montreal*

111.09 – Jet-driven redistribution of metal in galaxy clusters

The ICM in galaxy clusters is metal enriched, typically to about 30% of solar metallicity, out to large radii. However, metals should form mostly in galaxies and remained bound to their progenitor systems. To enrich the ICM, effective mixing of gas needs to occur across large scales. We carry out numerical simulations of mixing driven by AGN jets in dynamical galaxy clusters. These jets lift gas out of the center of the cluster, redistributing metals and adding energy to the ICM. We compare our results to X-ray observations of metallicity in clusters.

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111.10 – A Fossil Group in Formation

In the current picture of hierarchical structure formation, galaxy groups play a vital role as the seeds from which large assemblies of matter form. Compact groups are also important environments in which to watch the fueling of star formation and AGN activity, as the conditions are ideal for galaxy-galaxy interactions. We have identified a galaxy system that may represent an intermediate or transition stage in group evolution. Shakhbazyan 1 (or SHK 1) is a remarkably compact collection of about ten massive, red-sequence galaxies within a region 100 kpc across. Several of these galaxies show signs of AGN activity, and new, deep optical observations with the Discovery Channel Telescope reveal an extended stellar envelope surrounding the galaxies. This envelope is much more extended than what would be expected from a superposition of normal galaxy envelopes, and it indicates a large amount of intra-group starlight, evidence that the galaxies in SHK 1 are dynamically interacting.

We here present new Chandra spectral imaging observations of this unusual system that confirm the presence of an X-ray-emitting diffuse intra-group medium (IGM), with a temperature of 1.5 keV and X-ray luminosity of 1043 erg/s. Assuming hydrostatic equilibrium, the system is about 1/3 as massive as expected from the optical richness. In addition, three of the ten central galaxies exhibit signatures of X-ray AGN. The under-luminous IGM, high density of bright galaxies, and evidence for galaxy-galaxy interaction indicate that this system may be in a transition stage of galaxy merging, similar to that expected in the formation of a fossil group. Alternatively, SHK 1 may consist of multiple poor groups in the final stages of merging along our line of sight. We explore these scenarios and outline paths of future study for this enigmatic system.

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Institution(s): *1. MIT*

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112 – Gamma-Ray Bursts Poster Session

112.01 – The statistics of BAT-to-XRT flux ratio in GRB:Evidence for a characteristic value and its implications

We present the statistics of the ratio, R, between the prompt and afterglow ``plateau" fluxes of GRB. This we define as the ratio between the mean prompt energy flux in*Swift* BAT and the *Swift* XRT one, immediately following the steep transition between these two states and the beginning of the afterglow stage referred to as the ``plateau". Like the distribution of many other GRB observables, the histogram of R is log-normal with maximum at a value $R_m \sim 2000$, FWHM of about 2 decades and with the entire distribution spanning about 5 decades in the value of R. We note that the peak of the distribution is close to the proton-to-electron mass ratio $R_m \sim m_p/m_e=1836$, as proposed to be the case, on the basis of a specific model of the GRB dissipation process. It therefore appears that, in addition to the values of the energy of peak luminosity $E_p \sim m_ec^2$, GRB present us with one more quantity with an apparent characteristic value. The fact that the values of both these quantities (E_p and R) are consistent with the same specific model invoked to account for the efficient conversion of their relativistic proton energies to electrons, argues favorably for its underlying assumptions.

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

112.02 – A Homogeneous Dataset for Probing the Environments of Gamma-Ray Bursts

Studying the spectra of long gamma-ray bursts (GRBs) is providing greater clues about the environments in which they reside. Much of our understanding to date comes from spectral data obtained in the gamma-ray to X-ray. Studies of the environments of individual bursts have additionally included UV/optical data. However, because of the paucity of UV/optical data in the past, the soft-energy component has not been systematically included in these studies. The *Swift* Ultra-Violet/Optical Telescope (UVOT) has observed more GRBs in the UV/optical than any other telescope. From these observations we have generated a homogenous UV/optical GRB afterglow catalog. Coupling this data with archival *Swift* X-Ray Telescope (XRT) data, we examine the spectral evolution of GRBs in order to probe the circumburst environment. Particularly we examine the fraction of GRBs that have their cooling break between the optical and X-ray, and place limits on the number of bursts residing in a windy or ISM environment.

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112.03 – Studying the high redshift Universe with Athena

Athena is the second large mission selected in the ESA Cosmic Vision plan. With its large collecting area, high spectral-energy resolution (X-IFU instrument) and impressive grasp (WFI instrument), Athena will truly revolutionise X-ray astronomy. The most prodigious sources of high-energy photons are often transitory in nature. Athena will provide the sensitivity and spectral resolution coupled with rapid response to enable the study of the dynamic sky. Potential sources include: distant Gamma-Ray Bursts to probe the reionisation epoch and find 'missing' baryons in the cosmic web; tidal disruption events to reveal dormant supermassive and intermediate-mass black holes; and supernova explosions to understand progenitors and their environments.

Using detailed simulations, we illustrate Athena's extraordinary capabilities for transients out to the highest redshifts and show how it will be able to constrain the nature of explosive transients including gas metallicity and dynamics, constraining environments and progenitors.

Author(s): P. T. O'Brien[1]
Institution(s): *1. University of Leicester*

112.04 – GRB Polarization Measurements with CGRO/COMPTEL

We have embarked on a program to analyze CGRO/COMPTEL data in search for evidence of polarization in both transient sources and in brighter steady sources. We are pursuing this work because of the heightened interest in high energy polarimetry, the recognition that some high energy sources may be highly polarized (thus improving our chances of a making useful measurements), and the ready availability of modern computing resources that provide the ability to carry out more comprehensive simulations in support of the analysis. The only significant work done to date with regards to COMPTEL polarimetry was published almost 20 years ago and used a simplified mass model of COMPTEL for simulating the instrument response. Estimates of the minimum detectable polarization (MDP) near 1 MeV included 30% for a two-week observation of the Crab, as low as 10% for bright GRBs, and as low as 10% for bright solar flares. The data analysis performed at the time led to inconclusive results and suggested some unknown systematic error. We contend that a self-consistent analysis will be feasible with high fidelity simulations, simulations that were not easily generated 20 years ago. Our analysis utilizes the latest GEANT4 simulation tools in conjunction with a high-fidelity mass model of the COMPTEL instrument, and incorporate updated analysis tools originally developed by the COMPTEL collaboration. Given the nine years of COMPTEL data, we expect that this work will likely add to our understanding of the polarization properties of transient sources, such as GRBs and solar flares, as well as brighter steady sources, such as the Crab and Cyg X-1. Here we present results from simulations of the COMPTEL polarization response and examine prospects for studying GRB polarization.

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113 – Gravitational Waves Poster Session

113.01 – The Search for Gravitational Wave EM Counterparts with Swift

We present the plan to search for electromagnetic counterparts of Gravitational Waves (GWs) discovered during the current and upcoming runs of the LIGO and Virgo detectors. As we enter a period where the sensitivity of the current generation of GW detectors approaches a high probability of the first detection of a real GW signal, confirmation of the reality of these triggers will be greatly improved if an EM counterpart can be found. Swift's ability to rapidly respond to high priority target-of-opportunity observations, it's multi-wavelength capabilities and low overhead observing make it a seemingly ideal follow-up facility. However comparing the size of the expected GW error regions with the fields of view of the Swift XRT and UVOT telescopes, we find that covering the large GW error regions would require a unreasonably large number of pointings. We present our method of meeting this challenge, by both reducing the problem using Galaxy targeting, and by operating Swift in an entirely new way in order to cover the still large number of fields needed to chase down the EM counterpart before it disappears.

Author(s): Jamie Kennea[1], Phil Evans[2], Swift GW follow-up team[1]
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113.03 – INTEGRAL upper limits on gamma-ray emission associated with the gravitational wave event GW150914

Using observations of the INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL), we put tight upper limits on the gamma-ray and hard X-ray prompt emission associated with the gravitational wave event GW150914, discovered by the LIGO/Virgo collaboration. The omni-directional view of the INTEGRAL/SPI-ACS has allowed us to constrain the fraction of energy emitted in the hard X-ray electromagnetic component for the full high-probability sky region of LIGO/Virgo trigger. Our upper limits on the hard X-ray fluence at the time of the event range from F_γ=2x10^{-8} erg cm^{-2} to F_γ=10^{-6} erg cm^{-2} in the 75 keV - 2 MeV energy range for typical spectral models. Our results constrain the ratio of the energy promptly released in gamma-rays in the direction of the observer to the gravitational wave energy $E_\gamma/E_{GW}<10^{-6}$. We discuss the implication of gamma-ray limits on the characteristics of the gravitational wave source, based on the available predictions for prompt electromagnetic emission.

Author(s): Volodymyr Savchenko[1], Carlo Ferrigno7, Sandro Mereghetti5, Lorenzo Natalucci[6], Angela Bazzano[6], Enrico Bozzo7, Thierry J.-L. Courvoisier7, Soren Brandt[2], Lorraine Hanlon[8], Erik Kuulkers3, Philippe Laurent[1], François Lebrun[1], Jean-Pierre Roques9, Pietro Ubertini[6], Georg Weidenspointner4
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113.04 – Exploring Gravitational Waves in the Classroom

On September 14, 2015, the Laser Interferometer Gravitational-wave Observatory (LIGO) received the first confirmed gravitational wave signals. Now known as GW150914 (for the date on which the signals were received), the event represents the coalescence of two black holes that were previously in mutual orbit. LIGO's exciting discovery provides direct evidence of what is arguably the last major unconfirmed prediction of Einstein's General Theory of Relativity. The Education and Public Outreach group at Sonoma State University has created an educator's guide that provides a brief introduction to LIGO and to gravitational waves, along with two simple demonstration activities that can be done in the classroom to engage students in understanding LIGO's discovery. Additional resources have also been provided to extend student explorations of Einstein's Universe.

Author(s): Lynn R. Cominsky[1], Kevin M. McLin[1], Carolyn Peruta[1], Aurore Simonnet[1]
Institution(s): *1. Sonoma State Univ.*

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114 – Isolated Nss Poster Session

114.01 – Evolution of the X-ray Properties of the Transient Magnetar XTE J1810-197

We report on X-ray observations of the 5.54 s transient magnetar XTE J1810-197 using the XMM-Newton and Chandra observatories, analyzing new data from 2008 through 2014, and re-analyzing data from 2003 through 2007 with the benefit of these six years of new data. From the discovery of XTE J1810-197 during its 2003 outburst to the most recent 2014 observations, its 0.3-10 keV X-ray flux has declined by a factor of about 50 from 4.1E-11 to 8.1E-13 erg/cm^2/s. Its X-ray spectrum has now reached a steady state. Pulsations continue to be detected from a 0.3 keV thermal hot-spot that remains on the neutron star surface. The luminosity of this hot-spot exceeds XTE J1810-197's spin down luminosity, indicating continuing magnetar activity. We find that XTE J1810-197's X-ray spectrum is best described by a multiple component blackbody model in which the coldest 0.14 keV component likely originates from the entire neutron star surface, and the thermal hot-spot is, at different epochs, well described by an either one or two-component blackbody model. A 1.2 keV absorption line, possibly due to resonant proton scattering, is detected at all epochs. The X-ray flux of the hot spot decreased by approximately 20% between 2008 March and 2009 March, the same period during which XTE J1810-197 became radio quiet.

Author(s): Jason Alford[1]
Institution(s): *1. Columbia University*

114.02 – Unusual Braking Indices in Young X-ray Pulsars

Pulsars spin down over time. By measuring braking indices of pulsars, effectively the change in the spin-down rate over time, we can probe the underlying driving engine of the spin-down. For a magnetic dipole in a vacuum, n is predicted to be 3. To date, all measured braking indices are less than 3, which can be explained, e.g. by particle winds, changes in the magnetic field. In all models of braking indices, n should be nearly constant on year time-scales. Here, I will discuss two recent observation results that challenge this model, interestingly both coming from young X-ray pulsars with no detected radio emission. The first, a long-lived decrease in the braking index of PSR J1846-0258 following a burst of magnetar-like activity, and secondly, the first stationary braking index greater than three. Understanding neutron-star spin evolution is key to constraining these objects' long-term energy output and has relevance to topics ranging from pulsar wind nebulae and supernova remnants to core-collapse supernova rates, physics, and expected outcomes.

Author(s): Robert Frederic Archibald[6], Victoria M. Kaspi[6], Andrew P Beardmore[11], Neil Gehrels[3], Jamie Kennea[7], Eric V. Gotthelf[2], Robert Ferdman[6], Sebastien Guillot[8], Fiona Harrison[1], Evan Keane[9], Michael Pivovaroff[5], Daniel Stern[4], Shriharsh P. Tendulkar[6], John Tomsick[10]
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114.04 – Polar Cap Pair Production for an Axisymmetric Pulsar Requires General Relativity

Using an analytical approach coupled to a condition for pair production derived from particle in cell simulations, we show that pair production by curvature photons on magnetic field lines at the polar cap is inactive if general relativity is ignored. In particular, general relativisitic frame-dragging lowers the value of the Goldreich-Julian density at the polar cap compared to its value for a flat spacetime. This leads to a region of space-like current near the surface of the neutron star where pair production is possible.

However, even when general relativity is included, we show analytically that pair production on magnetic field lines is suppressed near the outer edge of the polar cap. This leads to the possibility of a ``vacuum" region of unscreened parallel electric field on open field lines near the last open field line. Such a vacuum region has indeed been observed in particle in cell simulations of the pulsar magnetosphere.

Because of the generality of our analytical approach (which does not assume a dipolar surface field), our conclusions are true independent of the detailed structure of the magnetic field at the surface of the neutron star. We confirm our analytical results by comparing them to force-free simulations of a pulsar with a dipolar surface field.

Author(s): Mikhail Belyaev[1]
Institution(s): *1. UC Berkeley*

114.05 – Young gamma-ray pulsar: from modeling the gamma-ray emission to the particle-in-cell simulations of the global magnetosphere

Accelerated charged particles flowing in the magnetosphere produce pulsar gamma-ray emission. Pair creation processes produce an electron-positron plasma that populates the magnetosphere, in which the plasma is very close to force-free. However, it is unknown how and where the plasma departs from the ideal force-free condition, which consequently inhibits the understanding of the emission generation. We found that a dissipative magnetosphere outside the light cylinder effectively reproduces many aspects of the young gamma-ray pulsar emission as seen by the Fermi Gamma-ray Space Telescope, and through particle-in-cell simulations (PIC), we started explaining this configuration self-consistently. These findings show that, together, a magnetic field structure close to force-free and the assumption of gamma-ray curvature radiation as the emission mechanism are strongly compatible with the observations. Two main issues from the previously used models that our work addresses are the inability to explain luminosity, spectra, and light curve features at the same time and the inconsistency of the electrodynamics. Moreover, using the PIC simulations, we explore the effects of different pair multiplicities on the magnetosphere configurations and the locations of the accelerating regions. Our work aims for a self-consistent modeling of the magnetosphere, connecting the microphysics of the pair-plasma to the global magnetosphere macroscopic quantities. This direction will lead to a greater understanding of pulsar emission at all wavelengths, as well as to concrete insights into the physics of the magnetosphere.

Author(s): Gabriele Brambilla[2], Constantions Kalapotharakos[1], Andrey Timokhin[1], Alice Kust Harding[1], Demosthenes Kazanas[1]
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114.06 – NICER observation of magnetars

The Neutron Star Interior Composition ExploreR (NICER) is a NASA Explorer Misson of Opportunity as an attached payload aboard the International Space Station (ISS), launch in August 2016. The NICER is planned to study the interior composition and structure within neutron stars via high precise measurement of their stellar mass and radius, also to investigate dynamic and energetic behaviors of their activities. This mission will enable pulsar rotation-resolved spectroscopy in the 0.2--12 keV energy band with large collection area (about twice of the XMM-Newton observatory for soft X-ray timing), precise time-tagging resolution (~200 nsec, 25 times better than RXTE), and high sensitivity (about 2e-14 erg/s/cm2 in the 0.5--10 keV, 5-sigma for 10 ksec exposure). As one of prime goals of the mission, we will describe the science planning of the NICER magnetar observations. The NICER is expected to provide monitoring of fainter magnetar sources which cannot be performed by Swift due to its little collective area. Deep observations of quiescent magnetars and high-B radio pulsars can be also performed with the NICER to study their spectral similarity as a key to investigate the connection between these two sub-classes. Finally, ToO programs are suitable to follow-up the magnate outburst relaxation down to much fainter flux level. We will introduce the NICER strategy of the magnetar observation.

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Institution(s): *1. Kyoto University, 2. McGill University, 3. NASA/GSFC*

114.07 – A Magnetar Wind Nebula: the Spin-down-Powered Wind is not Enough

Magnetars are a small class of slowly-rotating (P~2-12 s) highly magnetized (surface dipole fields ~10^{14}-10^{15} G) that show a variety of bursting activity, powered by the decay of their super-strong magnetic field. While many rotation-powered pulsars are surrounded by a pulsar wind nebula (PWN) powered by their spin-down MHD wind (the prime example being the Crab nebula), only now has the first magnetar wind nebula (MWN) been discovered in X-rays, around Swift J1834.9-0846. We have analyzed this system in detail to see what can be learned from it. We find good evidence that unlike normal PWNe, this MWN cannot be powered by its spin-down MHD wind alone. A considerable contribution to the MWN energy should come from a different source, most likely sporadic outflows associated with the magnetar's bursting activity. This suggests that the MWN may serve as a calorimeter, and provide a new and robust estimate for the magnetar's long-term mean energy output rate in outflows. We also discuss other interesting aspects of this system.

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Institution(s): *1. NASA/GSFC, 2. New York University, 3. New York University Abu Dhabi, 4. Rice University, 5. The George Washington University, 6. The Open University of Israel*

114.08 – Population synthesis of radio and gamma-ray millisecond pulsars using Markov Chain Monte Carlo techniques

We present preliminary results of a new population synthesis of millisecond pulsars (MSP) from the Galactic disk using Markov Chain Monte Carlo techniques to better understand the model parameter space. We include empirical radio and gamma-ray luminosity models that are dependent on the pulsar period and period derivative with freely varying exponents. The magnitudes of the model luminosities are adjusted to reproduce the number of MSPs detected by a group of thirteen radio surveys as well as the MSP birth rate in the Galaxy and the number of MSPs detected by *Fermi*. We explore various high-energy emission geometries like the slot gap, outer gap, two pole caustic and pair starved polar cap models. The parameters associated with the birth distributions for the mass accretion rate, magnetic field, and period distributions are well constrained. With the set of four free parameters, we employ Markov Chain Monte Carlo simulations to explore the model parameter space. We present preliminary comparisons of the simulated and detected distributions of radio and gamma-ray pulsar characteristics. We estimate the contribution of MSPs to the diffuse gamma-ray background with a special focus on the Galactic Center.
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).

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114.09 – Lastest Results from the X-ray Monitoring Campaign of AXP CXOU J17145.7-381031 in CTB 37B

The 3.82 s AXP CXOU J17145.7-381031 in the supernova remnant CTB 37B has one of the largest spin-down powers for a magnetar, and it may be the youngest one as well. Magnetars with the greatest spin-down power are SGRs, and a marked increase in their spin-down torque often preceds an outburst. In this regard, AXP CXOU J17145.7-381031 is very similar to SGR/AXP 1E 1547.0-5408, the magnetar with the largest spin-down power. We will report on the latest timing and spectral results from our on-going Chandra and XMM X-ray monitoring campaign on the AXP in CTB 37B. We also present a NuSTAR observation that reveals a separate, hard spectral component similar to that found for other magnetars.

Author(s): Eric V. Gotthelf[1], Jules P. Halpern[1]
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114.10 – Chandra Phase-Resolved Spectroscopy of the High-Magnetic-Field Pulsar B1509-58

We report on timing and spectral analysis of the young, high-magnetic-field pulsar B1509-58 using Chandra continuous-clocking mode observation. The on-pulsed X-ray spectrum can be described by a power law with a photon index of 1.16(2), which is flatter than those determined with RXTE/PCA and NuSTAR. This result supports the log-parabolic model for the broadband X-ray spectrum. With the unprecedented angular resolution of Chandra, we clearly identified off-pulsed X-ray emission from the pulsar. The spectrum is best fitted by a power law plus blackbody model. The latter component has a temperature of ~0.14 keV, which is similar to those of other young and high-magnetic-field pulsars, and lies between those of magnetars and typical rotational-powered pulsars. For the non-thermal emission of PSR B1509-58, we found that the power law component of the off-pulsed emission is significantly steeper than that of the on-pulsed one. We further divided the data into 24 phase bins and found that the photon index varies between 1.0 and 2.0 and anti-correlating with the flux. A similar correlation was also found in the Crab Pulsar, and this requires further theoretical interpretations. This work is supported by a GRF grant of Hong Kong Government under 17300215.

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114.11 – Fermi γ-ray Pulsars: Towards the Understanding of the Pulsed High-Energy Emission

Based on the Fermi observational data we reveal meaningful constraints for the dependence of the macroscopic parameters of dissipative pulsar magnetosphere models on the corresponding spin-down rate. Our models are specifications of the FIDO (Force-Free Inside, Dissipative Outside) model where the dissipative regions are outside the light-cylinder near the equatorial current sheet. These models provide not only the field geometry but also the necessary particle accelerating electric fields. Assuming emission due to curvature radiation, the FIDO models reproduce the observed light-curve phenomenology as depicted in the radio-lag vs peak-separation diagram obtained by Fermi. A direct and detailed comparison of the model spectral properties (cutoff energies and total γ-ray luminosities) with those observed by Fermi reveals the dependence of the macroscopic conductivity parameter on the spin-down rate providing a unique insight for the understanding of the physical mechanisms behind the high-energy emission in pulsar magnetospheres.

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

114.14 – The 3D Space and Spin Velocities of a Gamma-ray Pulsar

PSR J2030+4415 is a LAT-discovered 0.5My-old gamma-ray pulsar with an X-ray synchrotron trail and a rare Halpha bowshock. We have obtained GMOS IFU spectroscopic imaging of this shell, and show a sweep through the remarkable Halpha structure, comparing with the high energy emission. These data provide a unique 3D map of the momentum distribution of the relativistic pulsar wind. This shows that the pulsar is moving nearly in the plane of the sky and that the pulsar wind has a polar component misaligned with the space velocity. The spin axis is shown to be inclined some 95degrees to the Earth line of sight, explaining why this is a radio-quiet, gamma-only pulsar. Intriguingly, the shell also shows multiple bubbles that suggest that the pulsar wind power has varied substantially over the past 500 years.

Author(s): Roger W. Romani[1]
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114.16 – Pulsars at the Center of the Galaxy

Over the past few years, a number of groups using data from NASA's space-borne Fermi LAT instrument have identified excess gamma-ray flux toward the inner few degrees of the Galactic Center (GC), with an even larger significant excess within 1 degree of this region. At present there are two leading candidates for this excess: dark matter annihilation and a population of unresolved millisecond pulsars (MSPs). We are currently developing dedicated instrumentation to carry out a sensitive search for the pulsars in this region of the galaxy using a newly developed front end and receiver on a Deep Space Network large diameter antenna in Australia. In this presentation, we will provide an overview of the challenges encountered with pulsar searches at the GC region and a summary of previous and ongoing efforts to survey this region with radio telescopes. We will also provide preliminary results from our recent observations of the GC region at 2 and 8 GHz and will conclude with prospects for detection of perhaps hundreds of pulsars in this region with new generations of radio telescopes now under construction.

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114.17 – X-ray studies of the redback system PSR J2129-0429

We present new NuStar data of the redback millisecond pulsar (MSP) system PSR J2129-0429. Redback systems are important when it comes to understanding the evolution of MSPs, in terms of pulsar recycling, as they have been observed to transition between a state of accretion, where emission is in the optical and X-ray regimes, and a state of eclipsed radio pulsation. This system is particularly interesting due to some peculiarities: it has a more massive companion as well as a stronger magnetic field than other redbacks, indicating that the system is in a fairly early stage of recycling. It's X-ray lightcurve (as obtained from XMM-Newton data) has a very hard power-law component and exhibits an efficiency of a few percent in X-ray. With the NuStar data, the spectrum can be seen to extend to ~30 keV. Additionally, it shows strong orbital variation, about 5 times greater than is typical for other systems, and is also very clearly double peaked. Hints of similar peaks have been observed in the lightcurves of other redback systems, and so this system can help in understanding the intrabinary shock of eclipsing MSPs.

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115 – Laboratory Astrophysics and Data Analysis Poster Session

115.01 – Charge Exchange, from the Laboratory to Galaxy Clusters

X-ray emission due to charge exchange (CX) between solar wind ions and neutrals in comets and planetary atmospheres is ubiquitous in the solar system, and is also a significant foreground in all observations from low-Earth orbit. It is also possible that CX is common astrophysically, in any environment where hot plasma and cold gas interact. A current challenge is that theoretical models of CX spectra do not always accurately describe observations, and require further experimental verification. This is especially important to focus on now, as the recent launch of Astro-H is providing us with the first high-resolution spectra of extended x-ray sources. In order to improve our understanding and modeling of CX spectra, we take advantage of the laboratory astrophysics program at the Lawrence Livermore National Laboratory and use an Electron Beam Ion Trap (EBIT) to perform CX experiments, using the EBIT Calorimeter Spectrometer. We present experimental benchmarks that can be used to develop a more comprehensive and accurate CX theory. On the observational side, we also investigate the possibility of CX occurring in the filaments around the central galaxy of the Perseus cluster, NGC 1275. We use Chandra ACIS data, combined with what we know about laboratory CX spectra, to investigate the possibility of CX being a significant contributor to the x-ray emission.

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115.02 – XSPEC and PyXSPEC

I will describe recent changes and planned improvements for XSPEC and PyXspec.

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116 – Missions & Instruments Poster Session

116.01 – The Transient High Energy Sky and Early Universe Surveyor

The Transient High Energy Sky and Early Universe Surveyor is a mission which will be proposed for the ESA M5 call. THESEUS will address multiple components in the Early Universe ESA Cosmic Vision theme:
4.1 Early Universe,
4.2 The Universe taking shape, and
4.3 The evolving violent Universe.

THESEUS aims at vastly increasing the discovery space of the high energy transient phenomena over the entire cosmic history. This is achieved via a unique payload providing an unprecedented combination of: (i) wide and deep sky monitoring in a broad energy band(0.3 keV-20 MeV; (ii) focusing capabilities in the soft X-ray band granting large grasp and high angular resolution; and (iii) on board near-IR capabilities for immediate transient identification and first redshift estimate.

The THESEUS payload consists of: (i) the Soft X--ray Imager (SXI), a set of Lobster Eye (0.3--6 keV) telescopes with CCD detectors covering a total FOV of 1 sr; (ii) the X--Gamma-rays spectrometer (XGS), a non-imaging spectrometer (XGS) based on SDD+CsI, covering the same FOV than the Lobster telescope extending the THESEUS energy band up to 20 MeV; and (iii) a 70cm class InfraRed Telescope (IRT) observing up to 2 microns with imaging and moderate spectral capabilities.

The main scientific goals of THESEUS are to:
(a) Explore the Early Universe (cosmic dawn and reionization era) by unveiling the Gamma--Ray Burst (GRBs) population in the first billion years}, determining when did the first stars form, and investigating the re-ionization epoch, the interstellar medium (ISM) and the intergalactic medium (IGM) at high redshifts.

(b) Perform an unprecedented deep survey of the soft X-ray transient Universe in order to fill the present gap in the discovery space of new classes of transient; provide a fundamental step forward in the comprehension of the physics of various classes of Galactic and extra--Galactic transients, and provide real time trigger and accurate locations of transients for follow-up with next-generation facilities.

(c) Provide IR survey capabilities in space and strong guest observer possibilities, thus allowing a strong community involvement. All transient alerts will be public.

Author(s): P. T. O'Brien[1]
Institution(s): *1. University of Leicester*

116.02 – Laboratory demonstration of the piezoelectric figure correction of a cylindrical slumped glass optic

The X-ray Surveyor is a mission concept for a next generation X-ray observatory. This mission will feature roughly 30 times the effective area of the Chandra Observatory while matching its sub-arcsecond angular resolution. The key to meeting these requirements is lightweight, segmented optics. To ensure these optics achieve and maintain sub-arcsecond performance, we propose to use piezoelectric coatings for post-bonding and on-orbit figure correction. We have fabricated a cylindrical prototype optic with piezoelectric adjusters and measured its performance using optical metrology. We present the results of this laboratory figure correction and discuss their implications for an observatory featuring adjustable X-ray optics.

Author(s): Ryan Allured3, Edward Hertz3, Vanessa Marquez3, Vincenzo Cotroneo3, Margeaux L Wallace[2], Bianca Salmaso[1], Marta M Civitani[1], Susan Trolier-McKinstry[2], Alexey Vikhlinin3, Giovanni Pareschi[1], Paul B. Reid3
Institution(s): *1. Osservatorio Astronomico di Brera, 2. Pennsylvania State University, 3. Smithsonian Astrophysical Observatory*

116.03 – Simulation and Optimization of Soft Gamma-Ray Concentrator Using Thin Film Multilayer Structures

We are reporting the investigation result of channeling and concentrating soft gamma rays (above 100 keV) using multilayer thin films of alternating low and high-density materials. This will enable future telescopes for higher energies with same mission parameters already proven by NuSTAR. Base on initial investigations at Los Alamos National Laboratory (LANL) we are investigating of producing these multilayers with the required thicknesses and smoothness using magnetron sputter (MS) and pulsed laser deposition (PLD) techniques. A suitable arrangement of bent multilayer structures of alternating low and high-density materials will channel soft gamma-ray photons via total external reflection and then concentrate the incident radiation to a point. The high-energy astrophysics group at the UNH Space Science Center (SSC) is testing these structures for their ability to channel 122 keV gamma rays in the laboratory. In addition of experimental works, we have been working on gamma ray tracing model of the concentrator by IDL, making use of optical properties calculated by the IMD software. This modeling allows us to calculate efficiency and focal length for different energy bands and materials and compare them with experimental result. Also we will combine concentrator modeling result and detector simulation by Geant4 to archive a complete package of gamma-ray telescope simulation. If successful, this technology will offer the potential for soft gamma-ray telescopes with focal lengths of less than 10 m, removing the need for formation flying spacecraft and opening the field up to balloon-borne instruments and providing greatly increased sensitivity for modest cost and complexity.

Author(s): Farzane Shirazi5, Peter F. Bloser5, Paul H. Aliotta[2], Olof Echt[2], James E. Krzanowski4, Jason S Legere5, Mark L. McConnell5, John G. Tsavalas4, Emily N. Wong[1], R. Marc Kippen3
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116.04 – Analysis of Data from the Balloon Borne Gamma RAy Polarimeter Experiment (GRAPE)

The Gamma Ray Polarimeter Experiment (GRAPE), a balloon borne polarimeter for 50~300 keV gamma rays, successfully flew in 2011 and 2014. The main goal of these balloon flights was to measure the gamma ray polarization of the Crab Nebula. Analysis of data from the first two balloon flights of GRAPE has been challenging due to significant changes in the background level during each flight. We have developed a technique based on the Principle Component Analysis (PCA) to estimate the background for the Crab observation. We found that the background depended mostly on the atmospheric depth, pointing zenith angle and instrument temperatures. Incorporating Anti-coincidence shield data (which served as a surrogate for the background) was also found to improve the analysis. Here, we present the calibration data and describe the analysis done on the GRAPE 2014 flight data.

Author(s): Sambid K Wasti[1], Peter F. Bloser[1], Jason S Legere[1], Mark L. McConnell[1], James M. Ryan[1]
Institution(s): *1. University of New Hampshire*

116.05 – Polarization from Relativistic Astrophysical X-ray Sourses: The PRAXyS Small Explorer Observatory

Polarization is a sensitive probe of geometry near compact objects, but remains largely unexplored in the X-ray band. Polarization is expected from cosmic X-ray sources, yielding insight into the geometry of black hole emission, and the origin and nature of X-ray emission in neutron stars and magnetars. Recent progress with detectors capable of imaging the track of a photoelectron generated by a detection of a cosmic X-ray have made sensitive X-ray polarization observatories possible within the constraints of a NASA Small Explorer mission. We report on the observational capabilities and the scientific goals of the "Polarization from Relativistic Astrophysical X-ray Sources" (PRAXyS) Observatory. PRAXyS is a small explorer which has been selected by NASA for a phase A study.

Author(s): Timothy R. Kallman[2], Keith Jahoda[2], Chryssa Kouveliotou[1], The PRAXyS Team[2]
Institution(s): *1. George Washington University, 2. NASA/GSFC*

116.06 – Second launch of the Diffuse X-ray emission from the Local Galaxy (DXL) mission

The Diffuse X-ray emission from the Local Galaxy (DXL) is a sounding rocket mission to study the Solar Wind Charge Exchange (SWCX) and Local Hot Bubble (LHB) X-ray emission. After a successful launch of December 2012, DXL's capabilities were expanded by using two additional proportional counters and three unique filters for the launch of December 2015. Employing Be-, Band C-based plastic filters, DXL mission re-scanned the Helium Focusing Cone for better spectral and positional information (to address the IBEX controversy). In this paper, we will review the upgraded mission hardware and performance, while sharing some preliminary results from the latest observation.

Submitted for the DXL Collaboration

Author(s): Dhaka Mohan Sapkota[1]
Institution(s): *1. University of Miami*

116.08 – Compton-Pair Production Space Telescope (ComPair) for MeV Gamma-ray Astronomy

The gamma-ray energy range from a few hundred keV to a few hundred MeV has remained largely unexplored, mainly due to the challenging nature of the measurements, since the pioneering, but limited, observations by COMPTEL on the Compton Gamma-Ray Observatory (1991- 2000). This energy range is a transition region between thermal and nonthermal processes, and accurate measurements are critical for answering a broad range of astrophysical questions. We are developing a MIDEX-scale wide-aperture discovery mission, ComPair (Compton-Pair Production Space Telescope), to investigate the energy range from 200 keV to > 500 MeV with high energy and angular resolution and with sensitivity approaching a factor of 100 better than COMPTEL. This instrument will be equally capable to detect both Compton-scattering events at lower energy and pair-production events at higher energy. ComPair will build on the heritage of successful space missions including Fermi LAT, AGILE, AMS and PAMELA, and will utilize well-developed space-qualified detector technologies including Si-strip and CdZnTe-strip detectors, heavy inorganic scintillators, and plastic scintillators.

Author(s): Alexander Moiseev[1]
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116.09 – Proposal of balloon and satellite observations of MeV gammas using Electron Tracking Compton Camera for reaching a high sensitivity of 1 mCrab

ETCC with a gas Time Projection Chamber (TPC) and pixel GSO scintillators, by measuring electron tracks precisely, provides both a strong background rejection by dE/dx of the track and well-defined 2-dimensional Point Spread Function (PDF) with better than several degrees by adding the arc direction of incident gammas (SPD: Scatter Plane Deviation) with the ARM (angular Resolution Measure) direction measured in standard Compton Camera (CC). In 2006 its background rejection was revealed by SMILE-I balloon experiment with 10cm-cubic ETCC using the dE/dx of tracks. In 2013, 30cm-cube-ETCC has been developed to catch gammas from Crab in next SMILE-II balloon with >5sigma detection for 4 hrs. Now its sensitivity has been improved to 10sigma by attaining the angular resolution of the track (SPD angle) to that determined by multiple scattering of the gas. Thus, we show the ability of ETCC to give a better significance by a factor of 10 than that of standard CCs having same detection area by electron tracking?and we have found that SPD is an essential to define the PSF of Compton imaging quantitatively. Such a well-defined PSF is, for the first time, able to provide reliable sensitivity in Compton imaging without assuming the use of optimization algorithm. These studies uncover the uncertainties of CCs from both points of view of the intense background and the difficulty of the definition of the PSF, and overcome the above problems. Based on this technology, SMILE-II with 3atm CF4 gas is expected to provide a 5times better sensitivity than COMPTEL in one month balloon, and 4modules of 50cm-cube ETCCs would exceed over 10^-12 erg/cm^2s^1 (1mCrab) in satellite. Here we summarize the performance of the ETCC and new astrophysics opened in near future by high sensitive observation of MeV gamma-rays.

Author(s): Atsushi Takada[1], Toru Tanimori[1]
Institution(s): *1. Kyoto University*

116.10 – Soft x-ray blazed transmission grating spectrometer with high resolving power and extended bandpass

A number of high priority questions in astrophysics can be addressed by a state-of-the-art soft x-ray grating spectrometer, such as the role of Active Galactic Nuclei in galaxy and star formation, characterization of the Warm-Hot Intergalactic Medium and the "missing baryon" problem, characterization of halos around the Milky Way and nearby galaxies, as well as stellar coronae and surrounding winds and disks. An Explorer-scale, large-area (> 1,000 cm^2), high resolving power ($R = \lambda/\Delta\lambda > 3,000$) soft x-ray grating spectrometer is highly feasible based on Critical-Angle Transmission (CAT) grating technology. Still significantly higher performance can be provided by a CAT grating spectrometer on an X-ray-Surveyor-type mission. CAT gratings combine the advantages of blazed reflection gratings (high efficiency, use of higher diffraction orders) with those of conventional transmission gratings (low mass, relaxed alignment tolerances and temperature requirements, transparent at higher energies) with minimal mission resource requirements. They are high-efficiency blazed transmission gratings that consist of freestanding, ultra-high aspect-ratio grating bars fabricated from silicon-on-insulator (SOI) wafers using advanced anisotropic dry and wet etch techniques. Blazing is achieved through grazing-incidence reflection off the smooth grating bar sidewalls. The reflection properties of silicon are well matched to the soft x-ray band. Nevertheless, CAT gratings with sidewalls made of higher atomic number elements allow extension of the CAT grating principle to higher energies and larger dispersion angles. We show x-ray data from metal-coated CAT gratings and demonstrate efficient blazing to higher energies and larger blaze angles than possible with silicon alone. We also report on measurements of the resolving power of a breadboard CAT grating spectrometer consisting of a Wolter-I slumped-glass focusing mirror pair from Goddard Space Flight Center and CAT gratings, to be performed at the Marshall Space Flight Center Stray Light Facility.

Author(s): Ralf K. Heilmann[2], Alexander Robert Bruccoleri[1], Mark Schattenburg[2]
Institution(s): *1. Izentis LLC, 2. MIT*

116.11 – Cross-calibration of the CCD Instruments onboard the Chandra, Suzaku, Swift, and XMM-Newton Observatories using 1E 0102.2-7219

We report on our continuing efforts to compare the time-dependent calibrations of the current generation of CCD instruments onboard the Chandra, Suzaku, Swift, and XMM-Newton observatories using the brightest supernova remnant in the Small Magellanic Cloud, 1E 0102.2-7219 (hereafter E0102). This calibration is a function of time due to the effects of radiation damage on the CCDs and the accumulation of a contamination layer on the filters or CCDs. We desire a simple comparison of the absolute effective areas in the 0.5-1.0 keV bandpass. The spectrum of E0102 has been well-characterized using the RGS grating instrument on XMM-Newton and the HETG grating instrument on Chandra. We have developed an empirical model for E0102 that includes Gaussians for the identified lines, two absorption components, and two continuum components with different temperatures. In our fits, the model is highly constrained in that only the normalizations of the four brightest line complexes (the O VII triplet, the O VIII Ly-alpha line, the Ne IX triplet, and the Ne X Ly-alpha line) and an overall normalization are allowed to vary. In our previous study, we found that based on observations early in the missions, most of the fitted line normalizations agreed to within +/- 10%. We have now expanded this study to include more recent data from these missions using the latest calibration updates and we will report on the current level of agreement amongst these instruments.

This work is based on the activities of the International Astronomical Consortium for High Energy Calibration (IACHEC).

Author(s): Paul P. Plucinsky[2], Andrew P Beardmore[6], Adam Foster[2], Matteo Guainazzi[3], Frank Haberl[5], Eric Miller[4], Andrew Pollock[1], Steve Sembay[6], Martin Stuhlinger[1]
Institution(s): *1. ESAC, 2. Harvard-Smithsonian, CfA, 3. JAXA, 4. MIT, 5. MPE, 6. University of Leicester*

116.12 – Lessons Learned Designing and Building the Chandra Telescope

This poster offers some of the major lessons learned by key members of the Chandra Telescope team. These lessons are gleaned from our experiences developing, designing, building and testing the telescope and its subsystems, with 15 years of hindsight. Among the topics to be discussed are the early developmental tests, known as VETA-I and VETA-II, requirements derivation, the impact of late requirements and reflection on the conservatism in the design process. This poster offers some opinions on how these lessons can affect future missions.

Author(s): Jonathan Arenberg[1]
Institution(s): *1. Northrop Grumman*

116.13 – Low energy response of the NICER detectors and "threshold efficiency" effect

The Neutron Star Interior Composition ExploreR (NICER) is an instrument that is planned to be installed on the International Space Station in 2016 to study time-resolved spectra of the rapidly changing celestial ojects. The focal plane of the instrument consists of 56 Silicon Drift Detectors (SDDs). Signal from each SDD is fed to shaping amplifiers and triggering circuits that determine both amplitude and time of arrival for each "event".
Zero crossing timing circuit is used in order to suppress energy dependent "time walk". That is done with a chain producing a derivative of the shaped signal, and the same chain detects threshold crossings marking the arrival of an X-ray photon. Higher noise of the differentiated signal leads to a somewhat extended band of signal amplitudes close to the threshold value, for which detection efficiency is less than 100%. Detection efficiency in this area affects the low energy portion of the detector response, and is very well described by an error function. We will present accurate measurements of this effect, show the consequences for the instrument quantum efficiency and the shape of the response function and will describe the calibration procedures that would allow selection of optimal threshold values for each observation.

Author(s): Gregory Prigozhin[1], John Doty[2], Beverly LaMarr[1], Andrew Malonis[1], Ronald A. Remillard[1], Frank Scholze[3], Christian Laubis[3], Michael Krumrey[3]
Institution(s): *1. MIT, 2. Noqsi Aerospace, 3. PTB*

116.14 – Development Status of Adjustable X-ray Optics with 0.5 Arcsec Imaging for the X-ray Surveyor Mission Concept

The X-ray Surveyor mission concept is designed as a successor to the Chandra X-ray Observatory. As currently envisioned, it will have as much as 30-50 times the collecting area of Chandra with the same 0.5 arcsec imaging resolution. This combination of telescope area and imaging resolution, along with a detector suite for imaging and dispersive and non-dispersive imaging spectroscopy, will enable a wide range of astrophysical observations. These observations will include studies of the growth of large scale structure, early black holes and the growth of SMBHs, and high resolution spectroscopy with arcsec resolution, among many others. We describe the development of adjustable grazing incidence X-ray optics, a potential technology for the high resolution, thin, lightweight mirrors. We discuss recent advancements including the demonstration of deterministic figure correction via the use of the adjusters, the successful demonstration of integrating control electronics directly on the actuator cells to enable row-column addressing, and discuss the feasibility of on-orbit piezoelectric performance and figure monitoring via integrated semiconductor strain gauges. We also present the telescope point design and progress in determining the telescope thermal sensitivities and achieving alignment and mounting requirements.

Author(s): Paul B. Reid[1], Ryan Allured[1], Sagi ben-Ami[1], Vincenzo Cotroneo[1], Daniel A. Schwartz[1], Harvey Tananbaum[1], Alexey Vikhlinin[1], Susan Trolier-McKinstry[2], Margeaux L Wallace[2], Tom Jackson[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. The Pennsylvania State University*

116.16 – The HEASARC in 2016: 25 Years and Counting

The High Energy Astrophysics Archival Research Center or HEASARC (http://heasarc.gsfc.nasa.gov/) has been the NASA astrophysics discipline archive supporting multi-mission cosmic X-ray and gamma-ray astronomy research for 25 years, and, through its LAMBDA (Legacy Archive for Microwave Background Data Analysis: http://lambda.gsfc.nasa.gov/) component, the archive for cosmic microwave background data for the last 8 years. The HEASARC is the designated archive which supports NASA's Physics of the Cosmos theme (http://pcos.gsfc.nasa.gov/).

The HEASARC provides a unified archive and software structure aimed both at 'legacy' high-energy missions such as Einstein, EXOSAT, ROSAT, RXTE, and Suzaku, contemporary missions such as Fermi, Swift, XMM-Newton, Chandra, NuSTAR, etc., and upcoming missions, such as Astro-H and NICER. The HEASARC's high-energy astronomy archive has grown so that it presently contains more than 80 terabytes (TB) of data from 30 past and present orbital missions. The user community downloaded 160 TB of high-energy data from the HEASARC last year, i.e., an amount equivalent to twice the size of the archive.

We discuss some of the upcoming new initiatives and developments for the HEASARC, including the arrival of public data from the JAXA/NASA Astro-H mission, expected to have been launched in February 2016, and the NASA mission of opportunity Neutron Star Interior Composition Explorer (NICER), expected to be deployed in late summer 2016. We also highlight some of the new software and web initiatives of the HEASARC, and discuss our plans for the next 3 years.

Author(s): Stephen Alan Drake[1], Alan P. Smale[1]
Institution(s): *1. NASA/GSFC*

116.17 – The Fermi Guest Investigator program: Impactful Science and Groundbreaking Results

As an all-sky surveyor, the science impact from the Fermi Gamma-ray Space Telescope is limited by the number of scientists performing data analysis, and not by the number of objects observed by the spacecraft. To encourage this, the Fermi guest investigator (GI) program supports a variety of scientific inquiries that benefit overall Fermi science. The GI program also provides access to radio, optical, X-ray and VHE gamma-ray data and/or observing time, encouraging and enabling relevant multi-wavelength studies. This approach has allowed for new analyses and ideas to flourish, leading to world-class groundbreaking science and a number of unexpected discoveries. The program has also supported a number of multi-year, multi-wavelength observing programs resulting in a rich variety of publicly available resources. Here we describe the most significant results from the Fermi GI program, including those resulting from both sky-survey and target of opportunity pointed observations. We discuss the public resources the program has supported, both for broad-band data acquisition and for the development of new analysis methods and techniques. Additionally, we consider the ramifications of the existence of long-term multi-wavelength datasets, such as those enabled by the Fermi GI program, for future scientific inquiry.

Author(s): Elizabeth C. Ferrara[1]
Institution(s): *1. NASA/GSFC*

116.18 – AtomDB and PyAtomDB: Atomic Data and Modelling Tools for High Energy and Non-Maxwellian Plasmas

The release of AtomDB 3 included a large wealth of inner shell ionization and excitation data allowing accurate modeling of non-equilibrium plasmas. We describe the newly calculated data and compare it to published literature data. We apply the new models to existing supernova remnant data such as W49B and N132D. We further outline progress towards AtomDB 3.1, including a new energy-dependent charge exchange cross sections.

We present newly developed models for the spectra of electron-electron bremsstrahlung and those due to non-Maxwellian electron distributions.

Finally, we present our new atomic database access tools, released as PyAtomDB, allowing powerful use of the underlying fundamental atomic data as well as the spectral emissivities.

Author(s): Adam Foster[1], Randall K. Smith[1], Nancy S. Brickhouse[1], Xiaohong Cui[1]
Institution(s): *1. Harvard Smithsonian, CfA*

116.19 – X-ray Reflection Gratings: Technology Development Status Update

We present the current status in the development of X-ray reflection gratings. Gratings mounted in the off-plane configuration are capable of achieving high spectral resolving power concurrently with high diffraction efficiency. This will enable key soft X-ray spectroscopy science goals to be achieved. We have identified hurdles to practically achieving the theoretical performance goals. Here we present our methodologies to overcome these challenges. Furthermore, we discuss how we test these methods to quantify performance capabilities. The results of these tests are placed in the context of Technology Readiness Level (TRL) in order to demonstrate our current status and to discuss our plans for the future.

Author(s): Randall L. McEntaffer[1]
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116.20 – Status of the Balloon-Borne X-ray Polarimetry Mission X-Calibur

We report on the status of the balloon borne hard X-ray polairmetry mission X-Calibur. The missions combines a focussing hard X-ray mirror from the InFOCuS collaboration with a scattering polarimeter and the WASP (Wallops Arc Second Pointer) pointing system. The mission is scheduled for a conventonal ~1 day balloon flight in Fall 2016 and a long duration (~30 day) balloon flight from McMurdo (Ross Island) in 2018/2019. X-Calibur will allow us to measure ~5% polarization fractions for strong sources with a Crab-like enegry spectra and fluxes. The science targets of the first balloon flights will include the stellar mass black holes GRS 1915+105 and Cyg X-1, Her X-1, Sco X-1, and the Crab nebula and pulsar. The long duration balloon flight will target several X-ray binaries and the extragalactic mass accreting supermassive black hole Cen A. In this contribution we give an update on the status of the mission, and the expected science return.

Author(s): Henric Krawczynski4, Fabian Kislat4, David Stuchlik3, Takashi Okajima[2], Gianluigi de Geronimo[1]
Institution(s): *1. Brookhaven National Laboratory, 2. Goddard Space Flight Center, 3. Wallops Flight Facility, 4. Washington University in Saint Louis*

116.21 – Probing Sites of Extreme Astrophysics: the Science of ComPair

Fundamental astrophysics questions ranging from characterizing the formation, structure, and properties of astrophysical jets and compact objects to explaining a large population of unidentified sources found by the Fermi Large Area Telescope can be addressed by a mission that opens a window into the MeV range. ComPair aims to provide excellent continuum sensitivity and good angular resolution over a wide field-of-view in the underexplored region from ~200 keV to ~ 500 MeV. This critical band contains the onset, peak, or fall of a rich variety of nonthermal processes occurring at sites of strong gravitational and magnetic fields. ComPair will answer existing questions about well established source classes, such as MeV blazars, young luminous pulsars, and gamma-ray bursts, which are known to peak in energy flux within this band, as well as being poised to discover new source types and behaviors that have previously been unobservable.

Author(s): Elizabeth A. Hays[1]
Institution(s): *1. NASA/GSFC*

116.22 – HaloSat: A CubeSat to Map the Distribution of Baryonic Matter in the Galactic Halo

Approximately half of predicted baryonic matter in the Milky Way remains unidentified. One possible explanation for the location of this missing matter is in an extended Galactic halo. HaloSat is a CubeSat that aims to constrain the mass and distribution of the halo's baryonic matter by obtaining an all-sky map of O VII and O VIII emission in the hot gas associated with the halo of the Milky Way. HaloSat offers an improvement in the quality of measurements of oxygen line emission over existing X-ray observatories and an observation plan dedicated to mapping the hot gas in the Galactic halo. In addition to the missing baryon problem, HaloSat will assign a portion of its observations to the solar wind charge exchange (SWCX) in order to calibrate models of SCWX emission. We present here the current status of HaloSat and the progression of instrument development in anticipation of a 2018 launch.

Author(s): Drew M Miles[1]
Institution(s): *1. University of Iowa*

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117 – Solar and Stellar Poster Session

117.01 – NuSTAR Search for Hard X-ray Emission from the Star Formation Regions in Sh2-104

We present NuSTAR hard X-ray observations of Sh2-104, a compact Hii region containing several young massive stellar clusters (YMSCs). We have detected distinct hard X-ray sources coincident with localized VERITAS TeV emission recently resolved from the giant gamma-ray complex MGRO J2019+37 in the Cygnus region. Faint, diffuse X-ray emission coincident with the eastern YMSC in Sh2-104 is likely the result of colliding winds of component stars. Just outside the radio shell of Sh2-104 lies 3XMM J201744.7+365045 and nearby nebula NuSTAR J201744.3+364812, whose properties are most consistent with extragalactic objects. The combined XMM-Newton and NuSTAR spectrum of 3XMM J201744.7+365045 is well-fit to an absorbed power-law model with NH = (3.1+/-1.0)E22 1/cm^2 and photon index Gamma = 2.1+/-0.1. Based on possible long-term flux variation and lack of detected pulsations (<43% modulation), this object is likely a background AGN rather than a Galactic pulsar. The spectrum of the NuSTAR nebula shows evidence of an emission line at E = 5.6 keV suggesting an optically obscured galaxy cluster at z = 0.19+/-0.02 (d = 800 Mpc) and Lx = 1.2E44 erg/s. Follow-up Chandra observations of Sh2-104 will help identify the nature of the X-ray sources and their relation to MGRO J2019+37.

Author(s): Eric V. Gotthelf[1]
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117.02 – A Deep X-ray look at a very massive star: HETGS spectroscopy of the blue hypergiant Cyg OB2-12 (HIP 101364)

We have obtained a Chandra/HETGS spectrum of one of the most massive and luminous stars in the Galaxy: the blue hypergiant Cyg OB2-12 (HIP 101364, spectral type B3 Ia+). This is the first measurement at high resolution of X-ray spectral lines in a blue hypergiant and allows comparison of X-ray properties between massive stars at different but related evolutionary stages: O-type supergiants, luminous blue variables, Wolf-Rayet stars, and blue hypergiants stars. The new data provide a look at how the most massive stars shed mass during their pre-supernova evolution. We find that In Cyg OB2-12 the resolved Si and Mg lines are broadened by about 1000 km/s (FWHM). The lines, however, do not show appreciable centroid shifts (<100 km/s), which would be much larger for canonical moderately thick winds (~500 km/s). The He-like Mg XI lines show evidence of photo-excitation, implying a wind origin close to the UV-bright photosphere. The spectrum also indicates relatively high temperature plasma, up to 22 MK (1.9 keV), showing significant continuum and emission lines below 5A (above 2.5 keV). Hence, at first glance, the spectrum resembles neither an O-star thick wind, nor a magnetically confined (narrow-line) plasma. We will present more detailed wind models using both X-ray and UV spectra to constrain fundamental physical parameters of this star.

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Institution(s): *1. East Tennessee State University, 2. MIT Kavli Institute, 3. University of Potsdam, 4. University of Toronto*

117.03 – The Dynamo Clinical Trial

The Dynamo Clinical Trial evaluates long-term stellar magnetic health through periodic X-ray examinations (by the Chandra Observatory). So far, there are only three subjects enrolled in the DTC: Alpha Centauri A (a solar-like G dwarf), Alpha Cen B (an early K dwarf, more active than the Sun), and Alpha Canis Majoris A (Procyon, a mid-F subgiant similar in activity to the Sun). Of these, Procyon is a new candidate, so it is too early to judge how it will fare. Of the other two, Alpha Cen B has responded well, with a steady magnetic heartbeat of about 8 years duration. The sickest of the bunch, Alpha Cen A, was in magnetic cardiac arrest during 2005-2010, but has begun responding to treatment in recent years, and seems to be successfully cycling again, perhaps achieving a new peak of magnetic health in the 2016 time frame. If this is the case, it has been 20 years since A's last healthful peak, significantly longer than the middle-aged Sun's 11-year magnetic heartbeat, but perhaps in line with Alpha Cen A's more senescent state (in terms of "relative evolutionary age," apparently an important driver of activity). (By the way, don't miss the exciting movie of the Alpha Cen stars' 20-year X-ray dance.)

Author(s): Thomas R. Ayres1
Institution(s): *1. University of Colorado*

117.04 – The 3-year Solar Wind Charge Exchange Campaign with Suzaku: preliminary results

We performed a 3-year monitoring campaign of the Solar Wind Charge Exchange (SWCX) heliospheric emission with Suzaku. We targeted four nearby (~100 pc) high column density clouds that absorb the X-ray contribution from distant sources so that the leftover signal has local origin (and is expected to be dominated by SWCX). The targets have been selected for their position in the sky, in order to maximize the latitude and longitude range, to model how SWCX depends on the distribution of neutrals, and to follow the seasonal variations of the SWCX. Here we present the results of data analysis of the three years of observations and we show how they compare with existing models.

Author(s): Eugenio Ursino3, Massimiliano Galeazzi3, Wenhao Liu3, Dimitra Koutroumpa2, K. D. Kuntz1
Institution(s): *1. Johns Hopkins University, 2. LATMOS-IPSL/CNRS, 3. University of Miami*

117.05 – The velocity dependence of X-ray emission due to Charge Exchange: Applications in the Cygnus Loop

The fundamental collisional process of charge exchange (CX) has been been established as a primary source of X-ray emission from the heliosphere [1], planetary exospheres [2], and supernova remnants [3,4]. In this process, X-ray emission results from the capture of an electron by a highly charged ion from a neutral atom or molecule, to form a highly-excited, high charge state ion. As the captured electron cascades down to the lowest energy level, photons are emitted, including X-rays.
To provide reliable CX-induced X-ray spectral models to realistically simulate high-energy astrophysical environments, 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 various collisional velocities. Collisions of bare and H-like C to Al ions with H, He, and H_2 are considered. Using these line ratios, XSPEC models of CX emission in the northeast rim of the Cygnus Loop supernova remnant will be shown as an example with ion velocity dependence.

[1] Henley, D. B. & Shelton, R. L. 2010, ApJSS, 187, 388
[2] Dennerl, K. et al. 2002, A&A 386, 319
[3] Katsuda, S. et al. 2011, ApJ 730 24
[4] Cumbee, R. S. et al. 2014, ApJ 787 L31

Author(s): Renata Cumbee1, David Lyons1, Patrick Mullen1, Robin L. Shelton1, Phillip C. Stancil1, David R. Schultz2
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118 – Supernovae and Supernova Remnants Poster Session

118.01 – Constraining the Turbulence Scale and Mixing of a Crushed Pulsar Wind Nebula

Pulsar wind nebulae (PWNe) are synchrotron-emitting nebulae resulting from the interaction between pulsars' relativistic particle outflows and the ambient medium. The Snail PWN in supernova remnant G327.1-1.1 is a rare system that has recently been crushed by supernova reverse shock. We carried out radio polarization observations with the Australia Telescope Compact Array and found highly ordered magnetic field structure in the nebula. This result is surprising, given the turbulent environment expected from hydrodynamical simulations. We developed a toymodel and compared simple simulations with observations to constrain the characteristic turbulence scale in the PWN and the mixing with supernova ejecta. We estimate that the turbulence scale is about one-eighth to one-sixth of the nebula radius and a pulsar wind filling factor of 50-75%. The latter implies substantial mixing of the pulsar wind with the surrounding supernova ejecta.

This work is supported by an ECS grant of the Hong Kong Government under HKU 709713P. The Australia Telescope is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.

Author(s): Chi Yung Ng5, Y. K. Ma5, Niccolo Bucciantini4, Patrick O. Slane1, Bryan M. Gaensler2, Tea Temim3
Institution(s): *1. CfA, 2. Dunlap Institute for Astronomy and Astrophysics, 3. GSFC, 4. INAF, 5. The University of Hong Kong*

118.02 – Asymmetric Expansion of the Youngest Galactic Supernova Remnant G1.9+0.3

The youngest Galactic supernova remnant (SNR) G1.9+0.3, produced by a (likely) Type Ia SN that exploded around CE 1900, is strongly asymmetric at radio wavelengths but exhibits a bilaterally symmetric morphology in X-rays. It has been difficult to understand the origin of these contrasting morphologies. We present results of X-ray expansion measurements of G1.9+0.3 that illuminate the origin of the radio asymmetry. These measurements are based on comparing recent (2015), 400 ks-long Chandra observations with earlier Chandra observations that include 1 Ms-long 2011 observations. The mean expansion rate from 2011 to 2015 is 0.58% yr^{-1}, in agreement with previous measurements. We also confirm that expansion decreases radially away from the remnant's center along the major E-W axis, from 0.77% yr^{-1} to 0.53% yr^{-1}. Large variations in expansion are also present along the minor N-S axis. Expansion of the faint S rim and the outermost faint N rim is comparable to the mean expansion. But the prominent X-ray rim in the N, coincident with the outer edge of the bright radio rim that marks the primary blast wave there, is expanding more slowly. Its expansion relative to the S rim is only 0.47% yr^{-1}. At 8.5 kpc, this corresponds to a speed of about 5000 km/s, less than half of the overall blast wave speed of 12,000 km/s. Such strong deceleration of the northern blast wave most likely arises from the collision of SN ejecta with a much denser than average ambient medium there. The presence of the asymmetric ambient medium naturally explains the radio asymmetry. The SN ejecta have also been strongly decelerated in the N, but they expand faster than the blast wave. In several locations, significant morphological changes and strongly nonradial motions are apparent. The spatially-integrated X-ray flux continues to increase with time. As with Kepler's SN - the most recent historical SN in the Galaxy - the SN ejecta are likely colliding with the asymmetric circumstellar medium (CSM) ejected by the SN progenitor prior to its explosion. G1.9+0.3 fills the gap between distant Type Ia-CSM SNe and older Type Ia-CSM SNRs such as Kepler's SNR, providing us with a unique opportunity to learn about mysterious Type Ia progenitors.

Author(s): Kazimierz J. Borkowski3, David Green1, Peter Gwynne3, Una Hwang4, Robert Petre2, Stephen P. Reynolds3, Rebecca Willett5
Institution(s): *1. Cavendish Laboratory, 2. NASA/Goiddard Space Flight Center, 3. North Carolina State Univ., 4. University of Maryland, 5. University of Wisconsin-Madison*

118.03 – Spatially resolved spectroscopy analysis of the XMM-Newton large program on SN1006

We perform analysis of the XMM-Newton large program on SN1006 based on our newly developed methods of spatially resolved spectroscopy analysis. We extract spectra from low and high resolution meshes. The former (3596 meshes) is used to roughly decompose the thermal and non-thermal components and characterize the spatial distributions of different parameters, such as temperature, abundances of different elements, ionization age, and electron density of the thermal component, as well as photon index and cutoff frequency of the non-thermal component. On the other hand, the low resolution meshes (583 meshes) focus on the interior region dominated by the thermal emission and have enough counts to well characterize the Si lines. We fit the spectra from the low resolution meshes with different models, in order to decompose the multiple plasma components at different thermal and ionization states and compare their spatial distributions. In this poster, we will present the initial results of this project.

Author(s): Jiang-Tao Li5, Anne Decourchelle1, Marco Miceli3, Jacco Vink4, Fabrizio Bocchino2
Institution(s): *1. CEA Saclay, 2. INAF-Osservatorio Astronomico di Palermo, 3. Universita di Palermo, 4. University of Amsterdam, 5. University of Michigan*

118.04 – Smoothed Particle Inference Analysis of SNR RCW 103

We present preliminary results of applying a novel analysis method, Smoothed Particle Inference (SPI), to an XMM-Newton observation of SNR RCW 103. 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. Emission-weighted distributions of plasma properties, such as abundances and temperatures, are then extracted from the properties of the individual blobs. This technique has important advantages over analysis techniques which implicitly assume that remnants are two-dimensional objects in which each line of sight encompasses a single plasma. By contrast, SPI allows superposition of as many blobs of plasma as are needed to match the spectrum observed in each direction, without the need to bin the data spatially. This RCW 103 analysis is part of a pilot study for the larger SPIES (Smoothed Particle Inference Exploration of SNRs) project, in which SPI will be applied to a sample of 12 bright SNRs.

Author(s): Kari A. Frank1, David N. Burrows1, Vikram Dwarkadas2
Institution(s): *1. Pennsylvania State University, 2. University of Chicago*

118.05 – SN 1987A: Chandra Witnesses the End of an Era

Due to its age and close proximity, the remnant of SN 1987A is the only supernova remnant in which we can study the early developmental stages in detail, providing insight into stellar evolution, the mechanisms of the supernova explosion, and the transition from supernova to supernova remnant as the debris begins to interact with the surrounding circumstellar medium (CSM). We present the latest results from 16 years of Chandra ACIS observations of SN 1987A, now covering 4600 - 10500 days after the supernova. At approximately day 7500, the east-west asymmetry of the ring began to reverse, while the spectra and soft X-ray light curve revealed that the increase in soft X-ray emission slowed dramatically. This suggests the average CSM density encountered by the blast wave decreased at this time, likely due to lack of new emission from the densest clumps in the equatorial ring. Since day 9700 the soft X-ray light curve has flattened and remained approximately constant, evidence that the blast wave has now left the dense material of the known equatorial ring and is beginning to probe the unknown territory beyond.

Author(s): Kari A. Frank1, David N. Burrows1
Institution(s): *1. Pennsylvania State University*

118.06 – The X-ray and Radio Evolution of SN 2005kd

SN 2005kd is among the most luminous supernovae (SNe) to be discovered, at both X-ray and optical wavelengths. We have re-analysed all good angular resolution archival X-ray data available for SN 2005kd, combined with a 29ks Chandra observation obtained by our group. The data reveal an X-ray light curve that decreases faster than is expected for expansion in a steady wind. Our modelling of the data suggests that the early evolution is dominated by emission from the forward shock in a high-density medium. The observations suggest that the SN is expanding into a high density and high mass-loss rate environment, which is also supported by our analysis of the available radio data. Our results are used to estimate the mass-loss rate of the progenitor, variability in the wind mass-loss parameters prior to core-collapse, and the nature of the progenitor.

Author(s): Vikram Dwarkadas2, Cristina Romero-Canizales1, Ratuja Reddy2, Franz E. Bauer1
Institution(s): *1. Millennium Institute of Astrophysics, 2. Univ. of Chicago*

118.07 – Investigating the X-ray Emission from some of the Oldest Known X-ray Supernovae

The core-collapse of a massive star results in a supernova (SN) explosion, and a shock wave that expands outwards. The evolution of the shock wave, and the radius and morphology of the resulting remnant, depends on the density structure of the SN ejecta and surrounding medium. As the SN evolves, it sweeps up more material. The shock velocity, and therefore post-shock temperature (proportional to the square of the shock velocity), will consequently decrease. Thus we would expect a gradual evolution in the X-ray properties of the SN. While theoretical models anticipate this, very few SNe have observations over several decades that allow us to probe the time evolution of the X-ray emission and SN shocks.

We have compiled a database of most observed X-ray SNe. In this talk we will summarize the X-ray data on some of the oldest detected X-ray SNe. These observations bridge the gap between old SNe and young supernova remnants, and shed light on the transition of a supernova to a remnant. We will show lightcurves for those which have multiple detections, outline the variation in their X-ray luminosity with time, compare their X-ray emission to that of younger supernovae, and discuss the evolution of the shock parameters as the supernova continues on its journey towards becoming a remnant.

Author(s): Vikram Dwarkadas1, Danika Holmes1
Institution(s): *1. Univ. of Chicago*

118.08 – X-ray Properties of Supernova Remnants in Nearby Spiral Galaxies

More extragalactic SNRs have been detected in X-rays in nearby galaxies than in the Milky Way. Most of the X-ray detected SNRs were first identified optically, and then detected as soft X-ray sources in deep imaging observations with Chandra and in some cases XMM. Here, we discuss the large X-ray samples of SNRs in M33, M51, M83, and M101, with the goal of understanding which SNRs are detected in X-rays and which are not. Not surprisingly perhaps, most of the SNRs in these galaxies are middle-aged ones very few analogs of Cas A, the Crab or other young objects have been found. Trends of X-ray luminosity with diameter are absent, probably because the total amount of swept up material is the dominant factor in determining the X-ray luminosity of a SNR at a particular time. SNRs expanding into high density media evolve rapidly and have X-ray luminosities that peak at small diameters, whereas those expanding into lower density media evolve more slowly and have luminosities that peak later.

Author(s): Knox S. Long3, William P. Blair[1], K. D. Kuntz[1], P. Frank Winkler[2]
Institution(s): *1. JHU, 2. Middlebury College, 3. STScI*

118.09 – The Variable Crab Nebula: Evidence for a Connection between GeV flares and Hard X-ray Variations

In 2010, hard X-ray variations (Wilson-Hodge et al. 2011) and GeV flares (Tavani et al 2011, Abdo et al. 2011) from the Crab Nebula were discovered. Connections between these two phenomena were unclear, in part because the timescales were quite different, with yearly variations in hard X-rays and hourly to daily variations in the GeV flares. The hard X-ray flux from the Crab Nebula has again declined since 2014, much like it did in 2008-2010. During both hard X-ray decline periods, the Fermi LAT detected no GeV flares, suggesting that injection of particles from the GeV flares produces the much slower and weaker hard X-ray variations. The timescale for the particles emitting the GeV flares to lose enough energy to emit synchrotron photons in hard X-rays is consistent with the yearly variations observed in hard X-rays and with the expectation that the timescale for variations slowly increases with decreasing energy. This hypothesis also predicts even slower and weaker variations below 10 keV, consistent with the non-detection of counterparts to the GeV flares by Chandra (Weisskopf et al 2013). We will present a comparison of the observed hard X-ray variations and a simple model of the decay of particles from the GeV flares to test our hypothesis.

Author(s): Colleen A. Wilson-Hodge5, Alice Kust Harding4, Elizabeth A. Hays4, Michael L. Cherry[2], Gary L. Case[1], Mark H. Finger7, Peter Jenke[6], Xiao-Ling Zhang3
Institution(s): *1. La Sierra University, 2. LSU, 3. MPE, 4. NASA/GSFC, 5. NASA/MSFC, 6. UAH, 7. USRA/MSFC*

118.10 – The X-ray emission from Type IIn Supernovae as a Probe of the Stellar Environment and Supernova Progenitors

Core-collapse supernovae (SNe) are divided into different subclasses, depending mainly on their optical spectra or light curve. Type IIn supernovae (SNe) form one of the more recent subclasses, having been first identified in 1990. They are characterized by narrow lines on a broad base in the optical spectrum, and comprise 1 to 4% of the total core collapse SN population. There exists a wide diversity in SNe that exhibit IIn features, which has greatly complicated the task of identifying their progenitors.

IIns are observed to have the highest X-ray luminosity of all the SN classes, with luminosities generally exceeding 10^{38} ergs/s after several thousand days. Thus they are observable in X-rays even at late times, hundreds to thousands of days after explosion. They also exhibit the most diversity in their light curves. Many of the lightcurves tend to fall off rather steeply at late times, although one interesting case displayed a rising light curve for several thousand days. These characteristics, along with their high luminosities at other wavelengths, imply initial expansion in a very dense medium, with the densities decreasing rapidly a few years after explosion. Their X-ray spectra generally show distinct lines, suggesting that the emission is thermal in origin. The X-ray spectra can provide insight into the density structure, composition and metallicity of the surrounding medium, and the ionization level, through the spectra themselves as well as the X-ray absorption.

In this presentation we will show the lightcurves of almost all IIns that have been observed in the X-ray band, and compare and contrast them to the X-ray lightcurves of other types of SNe. We summarize the known properties of the X-ray emission from Type IIn SNe, and explore the implications for the SN environment, progenitor mass-loss and the identity of the progenitors.

Author(s): Vikram Dwarkadas[1]
Institution(s): *1. Univ. of Chicago*

118.11 – G156.2+5.7: SN 1006's older cousin

We report on the results of an analysis of the hydrodynamic properties of the supernova remnant G156.2+5.7. The models of Truelove and McKee (1999) are constrained by the observed amount of thermal X-ray emission, the measured temperature of the forward-shocked electrons, the inferred location of the reverse shock, and the observed amount of non-radiative Balmer line emission. The results suggest that the remnant is expanding into a low-density environment at a distance of at least 0.6 kpc. We review several clues that suggest the remnant was produced by a Type Ia supernova, which when combined with the other hydrodynamic constraints, implies that G156.2+5.7 is 2.6-15 kyr old, is 0.7-1.7 kpc from Earth (i.e. between Earth and the Perseus arm), and is surrounded by material with a hydrogen density of 0.046-0.075 cm^{-3}. These properties are consistent with the remnant having a low radio surface brightness with a highly-ordered and highly-polarized, tangential magnetic field that is inclined by 60-70 degrees relative to the Galactic plane. However, the inferred density and age are not consistent with the fitted value of the ionization age, which may indicate that the momentum distribution of the electrons is not a Maxwell-Boltzmann distribution, but instead includes a high-energy, non-thermal tail.

Author(s): Glenn E. Allen[2], Thomas Pannuti3, Allana Iwanicki[1], William Tan4
Institution(s): *1. Milton Academy, 2. MIT, 3. Morehead State University, 4. Northeastern*

118.12 – Radio Observations of the Pulsar Wind Nebula HESS J1303–631 with ATCA

Based on its enregy-dependent morphology the initially unidentified very high energy (VHE; E > 100 GeV) gamma-ray source HESS J1303–631 was recently associated with the pulsar PSR J1301–6305. Subsequent detection of X-ray and GeV counterparts further supports the identification of the H.E.S.S. source as evolved pulsar wind nebula (PWN). Recent radio observations of the PSR J1301–6305 region with ATCA dedicated to search for the radio counterpart of HESS J1303-631 are reported here. Observations at 5.5 GHz and 7.5 GHz do not reveal any extended emission associated with the pulsar. The analysis of the archival 1.384 GHz and 2.368 GHz data also does not show any significant emission. The 1.384 GHz data reveal a hint of an extended shell-like emission in the same region which might be a supernova remnant. The implications of the non-detection at radio wavelengths on the nature and evolution of the PWN as well as the possibility of the SNR candidate being a birth place of PSR J1301–6305 are discussed.

Author(s): Iurii Sushch5, Igor Oya3, Ullrich Schwanke4, Simon Johnston[2], Matthew Dalton[1]
Institution(s): *1. Active Space Technologies GmbH, 2. Australia Telescope National Facility, 3. DESY Zeuthen, 4. Humboldt University of Berlin, 5. North-West University*

119 – WDs & CVs Poster Session

119.01 – Astrophysical Boundary Layers: A New Picture

Accretion is a ubiquitous process in astrophysics. In cases when the

magnetic field is not too strong and a disk is formed, accretion can proceed through the mid plane all the way to the surface of the central compact object. Unless that compact object is a black hole, a boundary layer will be formed where the accretion disk touches its surfaces. The boundary layer is both dynamically and observationally significant as up to half of the accretion energy is dissipated there.
Using a combination of analytical theory and computer simulations we show that angular momentum transport and accretion in the boundary layer is mediated by waves. This breaks with the standard astrophysical paradigm of an anomalous turbulent viscosity that drives accretion. However, wave-mediated angular momentum transport is a natural consequence of "sonic instability." The sonic instability, which we describe analytically and observe in our simulations, is a close cousin of the Papaloizou-Pringle instability. However, it is very vigorous in the boundary layer due to the immense radial velocity shear present at the equator.
Our results are applicable to accreting neutron stars, white dwarfs, protostars, and protoplanets.

Author(s): Mikhail Belyaev3, Roman R. Rafikov[1], James Mclellan Stone[2]
Institution(s): *1. Institute for Advanced Study, 2. Princeton University, 3. UC Berkeley*

120 – XRBs and Population Surveys Poster Session

120.01 – The Ionized and Variable Outflow in the Low-Mass X-Ray Binary GX 13+1

We present the analysis of 7 Chandra HETG and 16 simultaneous RXTE PCA observations of GX 13+1, a persistent neutron star low-mass X-ray binary. The observations cover activity between 2002 and 2011. The 0.5-10 keV continuum was consistent with a two component model, either a blackbody plus power law or multicolor disk and blackbody across luminosities of (5-7)x10^{37} erg sec^{-1}, modified by a neutral absorption column requiring a silicon overabundance. We have identified significantly blue-shifted ($v_{outflow}$ > 500 km sec^{-1}) Kα Fe, Ca, S, and Si hydrogen-like lines in all HETG observations, as well hydrogen-like Ar and Mg lines in the majority of observations. The significant outflow can be modeled as a photoionized plasma with an ionization parameter ≥ 3.5. For the first time we map the occurrence of these wind outflows onto the color-color diagram of GX 13+1 and compare their location with that of the jet outflows in this system. We will further present variable X-ray properties of the wind in GX 13+1 and discuss suggested launching mechanisms as well as how its properties relate to the wind-accretion state in low-mass X-ray binaries.

Author(s): Jessamyn Allen1, Norbert S. Schulz[2], Jeroen Homan[2], Deepto Chakrabarty[1]
Institution(s): *1. Department of Physics, MIT, 2. Kavli Institute for Astrophysics & Space Research, MIT*

120.02 – The formation efficiency of high-mass X-ray binaries in our two nearest star-forming galaxies

We present the results of our investigation of the link between high-mass X-ray binaries (HMXBs) and star formation in the Magellanic Clouds, our nearest star-forming galaxies. Using the most complete census of HMXBs in the Large Magellanic Cloud (LMC) and the published spatially resolved star-formation history map of this galaxy, we find that the HMXBs (and as expected the X-ray pulsars) are present in regions with star-formation bursts ~6-25 Myr ago. In contrast, this population peaks at later ages (~25-60 Myr ago) in the Small Magellanic Cloud (SMC). Thus, this study (in combination with previous works) reinforces the idea that the HMXBs are associated with young stellar populations of ages ~10-40 Myr. In addition, we estimate an HMXB production rate of 1 system per ~($23.0_{-4.1}^{+4.4}$)×10^{-3} M⊙/yr or 1 system per ~143M⊙ of stars formed during the associated star-formation episode. Therefore, the formation efficiency of HMXBs in the LMC is ~17 times lower than that in the SMC. We attribute this difference primarily in the different ages and metallicity of the HMXB populations in the two galaxies. We also set limits on the kicks imparted on the neutron star during the supernova explosion. We find that the time elapsed since the supernova kick is ~3 times shorter in the LMC than the SMC. This in combination with the average offsets of the HMXBs from their nearest star clusters results in ~4 times faster transverse velocities for HMXBs in the LMC than in the SMC.

Author(s): Vallia Antoniou1, Andreas Zezas[1]
Institution(s): *1. Smithsonian Astrophysical Observatory*

120.03 – NuSTAR discovers a cyclotron line and reveals the spinning up of the accreting X-ray pulsar IGR J16393-4643

After several misclassifications, IGR J16393-4643 is now known to be a high-mass X-ray binary consisting of a heavily-absorbed pulsar that is likely paired with a massive and distant B star. It was observed for 50-ks by NuSTAR in the 3--79 keV energy band, complemented by a contemporaneous 2-ks observation with Swift-XRT. These observations enabled the discovery of a cyclotron resonant scattering feature with a centroid energy of 29.3(+1.1/-1.3) keV. This allowed us to measure the magnetic field strength of the neutron star for the first time: B = (2.5±0.1)×10^{12} G. The known pulsation period is now observed at 904.0±0.1 s. Since 2006, the neutron star has undergone a long-term spin-up trend at a rate of dP/dt = -2×10^{-8} s s^{-1} (-0.6 s per year, or a frequency derivative of dν/dt = 3×10^{-14} Hz s^{-1}). In the power density spectrum, a break appears at the pulse frequency which separates the zero slope at low frequency from the steeper slope at high frequency. This addition of angular momentum to the neutron star could be due to the accretion of a quasi-spherical wind, or it could be caused by the transient appearance of a prograde accretion disk that is nearly in corotation with the neutron star whose magnetospheric radius is around 2×10^{8} cm.

Author(s): Arash Bodaghee5, John Tomsick[10], Francesca Fornasini[10], Roman Krivonos[9], Daniel Stern[6], Kaya Mori[2], Farid Rahoui[4], Steven E. Boggs[10], Finn Christensen[3], William W. Craig[7], Charles James Hailey[2], Fiona Harrison[1], William Zhang[8]
Institution(s): *1. Caltech, 2. Columbia University, 3. Danish Technical University, 4. European Southern Observatory, 5. Georgia College and State University, 6. JPL-Caltech, 7. Lawrence Livermore National Laboratory, 8. NASA's GSFC, 9. Space Research Institute (IKI), 10. University of California, Berkeley*

120.04 – Multiwavelength Studies of Transitional Millisecond Pulsars

The recent discovery of three millisecond pulsar (MSP) binary systems that alternate between clearly distinguishable rotation- and accretion-powered states have revealed a new aspect of compact binaries containing neutron stars. These so-called transitional MSP systems hold the promise to elucidate the poorly-understood transition mechanism of pulsars between accretion and rotation power, as well as the detailed physics of accretion onto magnetized objects and the attendant outflows/jets. In this talk, I will present the rich phenomenology of transitional MSPs as revealed by our on-going X-ray, optical, and radio observing campaigns and discuss prospects for expanding the sample of these objects using the forthcoming Neutron Star Interior Composition Explorer X-ray timing instrument.

Author(s): Slavko Bogdanov2, Anne M Archibald[1], Cees Bassa[1], Adam T Deller[1], Jason Hessels[1], Jules P. Halpern[2], Amruta Jaodand[1]
Institution(s): *1. ASTRON, 2. Columbia University*

120.05 – Enhanced X-ray Emission from Early Universe Analog Galaxies

X-rays from binaries containing compact objects may have played an important role in heating the early Universe. Here we discuss our findings from X-ray studies of blue compact dwarf galaxies (BCDs), Lyman break analogs (LBAs), and Green Pea galaxies (GP), all of which are considered local analogs to high redshift galaxies. We find enhanced X-ray emission per unit star-formation rate which strongly correlates with decreasing metallicity. We find evidence for the existence of a L_X-SFR-Metallicity plane for star-forming galaxies. The exact properties of X-ray emission in the early Universe affects the timing and morphology of reionization, both being observable properties of current and future radio observations of the redshifted 21cm signal from neutral hydrogen.

Author(s): Matthew Brorby4, Philip Kaaret4, Andrea H. Prestwich[2], I. Felix Mirabel[1], Hua Feng3
Institution(s): *1. CEA-CEN Saclay, 2. Harvard-Smithsonian CfA, 3. Tsinghua University, 4. University of Iowa*

120.06 – An Investigation of Luminous X-Ray Pulsars: Exploring Accretion Onto Magnetized the Neutron Star LMC X-4

X-ray pulsars are neutron stars in which magnetic forces dominate accretion within the magnetosphere. These systems offer unique laboratories to study magnetic accretion and the behavior of matter under extreme densities, magnetic fields, and gravitational forces. Using joint observations with NuSTAR and XMM-Newton, we observe the complete precession of the warped accretion disk around the X-ray pulsar LMC X-4, and measure the relative phase between the pulsar beam and the softer X-ray photons reprocessed by the disk. This allows us to perform tomography to explore the inner magnetized accretion flow. Additionally, we investigate the unusual flaring events observed from LMC X-4 during October and November of 2015.

Author(s): McKinley Brumback[1]
Institution(s): *1. Dartmouth College*

120.07 – A test of the nature of the Fe K Line in the neutron star low-mass X-ray binary Serpens X-1

Broad Fe K emission lines have been widely observed in the X-ray spectra of black hole systems, and in neutron star systems as well. The intrinsically narrow Fe K fluorescent line is generally believed to be part of the reflection spectrum originating in an illuminated accretion disk, and broadened by strong relativistic effects. However, the nature of the lines in neutron star LMXBs has been under debate. We therefore obtained the longest, high-resolution X-ray spectrum of a neutron star LMXB to date with a 300 ks Chandra HETGS observation of Serpens X-1. The observation was taken under the "continuous clocking" mode and thus free of photon pile-up effects. We carry out a systematic analysis and find that the blurred reflection model fits the Fe line of Serpens X-1 significantly better than a broad Gaussian component does, implying that the relativistic reflection scenario is much preferred. Chandra HETGS also provides highest spectral resolution view of the Fe K region and we find no strong evidence for additional narrow lines.

Author(s): Chia-Ying Chiang[12], Edward Cackett[12], Jon M. Miller[10], Didier Barret7, Andrew C Fabian[8], Antonino D'Ai[1], Michael Parker[8], Sudip Bhattacharyya4, Luciano Burderi5, Tiziana Salvo[6], Elise Egron[2], Jeroen Homan3, Rosario Iaria[6], Dacheng Lin[11], M. Coleman Miller9
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120.08 – A Multi-Wavelength Study of the Gamma-Ray Binary 1FGL J1018.6-5856

1FGL J1018.6-5856, the first gamma-ray binary discovered by the Fermi Large Area Telescope (LAT), consists of an O6 V((f)) star and suspected rapidly spinning pulsar. While 1FGL J1018.6-5856 has been postulated to be powered by the interaction between a relativistic pulsar wind and the stellar wind of the companion, a microquasar scenario where the compact object is a black hole cannot be ruled out. We present the first extensive multi-wavelength analysis of 1FGL J1018.6-5856 with the Australia Telescope Compact Array (ATCA), Fermi LAT and the Swift X-ray Telescope (XRT) to better determine the properties of the 16.531$\pm$0.006 day orbital modulation. The radio amplitude modulation is found to decline with increasing frequency, which is a possible indication of the presence of free-free absorption. This is further supported by the absence of clear modulation in the 33.0 and 35.0\,GHz bands, which were not previously reported. The best-fit spectral model of the Swift XRT data consists of a featureless power law with index $\Gamma\sim$1.3--1.7 modified by an absorber that fully covers the source. This is possible evidence that 1FGL J1018.6-5856 is a non-accreting system.

Author(s): Joel Barry Coley[2], Robin Corbet5, Chi C. Cheung3, Guillaume Dubus4, Philip Edwards[1], Vanessa McBride[6], Jamie Stevens[1]
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120.09 – The broadband spectrum of Centaurus X-3

We present an analysis of a Suzaku observation of the accreting pulsar and high mass X-ray binary Centaurus X-3. The observation was performed in 2008 and covers one 2.1 day binary orbit. Strong flux and hardness variability is present in the energy range from 0.8 to 60 keV. We selected a part of the observation covering ~40% of the first half of the orbit during which the spectral shape was stable and less absorbed than during other parts of the observation. We confirm earlier results that the broadband spectrum can be modeled with a
cutoff power law modified by a partial absorber, three iron lines -- from near-neutral, helium-like, and hydrogen-like iron --, and a cyclotron resonant scattering line at 30 keV. The pulse profile shows a shift above the cyclotron line energy which is qualitatively consistent with recent theoretical predictions. In addition we find that the presence of the so-called ``13 keV'' bump is model dependent and that there are indications for further line-like spectral components at 1 keV and 6 keV and a broader residual around 2 keV. We also apply the newly implemented radiation dominated radiative shock model for luminous accretion pulsars by Becker and Wolff (2007, ApJ 654, 435) to model the broadband spectrum. Replacing the cutoff power law with the physical continuum while retaining all other components we obtain a similar goodness of fit as before. From the physical continuum model we determine a mass accretion rate of ~2.17 x 10^17 g/s, an accretion column radius of 65 (+12, -4) m, and a temperature of the accreted plasma of 3.1 (+0.4, -0.1) keV.

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120.10 – Driving of Accretion Disk Variability by the Disk Dynamo

Variability is a ubiquitous feature of emission from accreting objects, but many questions remain as to how the variability is driven and how it relates to the underlying accretion physics. In this talk I will discuss recent results from a long, semi-global MHD simulation of a thin accretion disk around a black hole used to perform a detailed study of the fluctuations in the internal disk stress and the influence these fluctuations have on the accretion flow. In the simulation, low frequency fluctuations of the effective α-parameter in the disk are linked to oscillations of the disk dynamo. These fluctuations in the effective alpha parameter drive “propagating fluctuations” in mass accretion rate through the disk that qualitatively resemble the variability from astrophysical black hole systems. The mass accretion rate has several of the ubiquitous phenomenological properties of black hole variability, including log-normal flux distributions, RMS-flux relationships, and radial coherence.

Author(s): J. Drew Hogg[1], Christopher S. Reynolds[1]
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120.11 – X-Ray Reflection of Thermonuclear Bursts from Neutron Stars: Constraining Flames with RXTE and an Outlook on NICER

Thermonuclear X-ray bursts observed from accreting neutron stars are employed to study, e.g., the nuclear physics of rare isotopes and the dense matter equation of state. Recent observations indicate that bursts strongly affect their accretion environment, and reprocessed burst emission may reflect off the inner accretion disk. The spectra of the short (10-100s) bursts are, however, of insufficient quality to accurately separate the neutron star signal from accretion disk emission and burst reflection. Only for two rare "superbursts" with durations of several hours did RXTE/PCA spectra show burst reflection signatures. We discuss the case of 4U 1636-536, where the reflection signal traced the evolution of the ionization state of the inner disk. Our simulations show that a large reflection fraction may indicate that the disk puffs up due to burst irradiation. After separating the direct burst emission from reflection, we show that the rise of the superburst light curve is shaped by a stalling carbon flame. In the near future, the Neutron Star Interior Composition ExploreR (NICER) will have a band-pass that extends below 2 keV, where reflection dominates the burst spectrum, and which was not probed by RXTE. Therefore, NICER will be able to detect reflection features during the frequent short bursts. NICER will open a new field of studying the interaction of bursts and the accretion environment, which will inform us of which bursts are optimally suited for neutron star mass-radius measurements.

Author(s): Laurens Keek[1]
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120.12 – The Recent Outburst of SMC X-2 as seen by Swift, MAXI and NuSTAR

We present results from the latest outburst of the Be/X-ray binary system SMC X-2, which in late 2015 entered it's first X-ray outburst since 2000. SMC X-2 was first discovered in 1977 by the SAS-3 satellite, and hosts a 2.37s period pulsar. Regular, almost daily, Swift observations of SMC X-2 were performed during the entirety of the latest outburst, from first detection by MAXI to it's rapid turn off and return back to quiescence. These observations have allowed us to measure with the flux, spectral and temporal properties of SMC X-2. Timing analysis of observation by the Swift X-ray telescope allowed us to track the evolution of the pulsar spin period, and in addition modeling of the orbital parameters of the system by measuring changes in the pulsar spin period due to Doppler effects. In addition we report on an observation of SMC X-2 taken with NuSTAR, which allowed both to better measure the continuum fit above 10 keV, and to perform a sensitive measure of the pulse profile and period of the source.

Author(s): Jamie Kennea[2], Malcolm J. Coe[3], Silas Laycock[4], Tony Bird[3], Elizabeth Bartlett[6], Lee Townsend[6], Vanessa McBride[6], Robin Corbet[5], Frank Haberl[1], Georgios Vasilopoulos[1]
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120.13 – Measuring neutron star masses and radii using NICER observations of X-ray oscillations

Precise and reliable simultaneous measurements of the mass and radius of several neutron stars with different masses would provide valuable guidance for improving models of the properties of cold dense matter. The prime scientific goal of the Neutron star Interior Composition ExploreR (NICER) is to make such measurements by fitting energy-dependent waveform models to the thermal X-ray oscillations observed from rotation-powered millisecond pulsars. These oscillations are thought to be produced as hotter regions of the stellar surface near one or both of the star's magnetic poles rotate around the star at the star's spin frequency. We first discuss the phenomenology and modeling of these oscillations. We then present the results of parameter estimation studies using synthetic waveform data and Bayesian statistical methods. The synthetic and model waveforms used in this study were computed using the X-ray spectra and radiation beaming patterns given by models of the cool hydrogen atmospheres that NICER is expected to observe. Finally, we discuss the causes and expected sizes of the uncertainties in radius and mass estimates that will be made by NICER using this method.

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120.14 – *NUSTAR* AND *XMM-Newton* Observations of the Neutron Star X-Ray Binary 1RXS J180408.9-34205

We report on observations of the neutron star (NS) residing in the low-mass X-ray binary 1RXS J180408.9-34205 taken 2015 March by *NuSTAR* and *XMM-Newton* while the source was in the hard spectral state. We find multiple reflection features (Fe Kα detected with *NuSTAR*; N VII, O VII, and O VIII detected in the RGS) from different ionization zones. Through joint fits using the self consistent relativistic reflection model RELXILL, we determine the inner radius to be 6.6(+13.2,−0.6) Rg. We find the inclination of the system to be between 18-29 degrees. If the disk is truncated at a radius greater than the innermost stable circular orbit (ISCO), then the position at which the inner disk terminates likely corresponds to the magnetospheric radius. For a spin parameter of a = 0, we estimate a conservative upper limit on the strength of the magnetic field to be $B \le (0.9 - 3.0) \times 10^9$ G at the magnetic poles depending on the choice of conversion factor between spherical and disk accretion.

Author(s): Renee Ludlam[7], Jon M. Miller[7], Edward Cackett[8], Andrew C Fabian[3], Matteo Bachetti[2], Michael Parker[3], John Tomsick[6], Didier Barret[5], Lorenzo Natalucci[4], Vikram Rana[1], Fiona Harrison[1]
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120.15 – X-Ray Burst Oscillations: From Flame Spreading to the Cooling Wake

Type I X-ray bursts are thermonuclear flashes observed from the surfaces of accreting neutron stars (NSs) 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. To date there have not been any quantitative studies that consistently track the oscillation amplitude both during the rise and decay (cooling tail) of bursts. In this talk I will discuss 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. I will present results for several such "cooling wake" models, a "canonical" cooling model where each patch on the NS surface heats and cools identically, or with a latitude-dependent cooling timescale set by the local effective gravity, and an "asymmetric" model where parts of the star cool at significantly different rates. We show that while the canonical cooling models can generate oscillations in the tails of bursts, they cannot easily produce the highest observed modulation amplitudes. Alternatively, a simple phenomenological model with asymmetric cooling can achieve higher amplitudes consistent with the observations. I will discuss how the combination of the light curve and fractional amplitude evolution can constrain the properties of the flame spreading, such as ignition latitude, the flame spreading geometry and speed, and its latitudinal dependence which would be important for measuring NSs masses and radii using X-ray burst oscillations.

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

120.16 – Cygnus X-3 Little Friend's Counterpart, the Distance to Cygnus X-3 and Jets (Oh My!)

Chandra observations have revealed a feature within 16" of Cygnus X-3 which varied in phase with Cygnus X-3. This feature was shown to be a Bok globule which is along the line of sight to Cygnus X-3. We report on observations made with Submillimeter Array (SMA) to search for molecular emission from this globule, also known as Cygnus X-3's "little friend." We have found a counterpart in both 12CO and 13CO emission. From the velocity shift of the molecular lines we are able determine a kinematic distance to the little friend and in turn a distance to Cygnus X-3. The uncertainties in this distance estimate to Cygnus X-3 are less than 10%. An additional unexpected discovery was that Cygnus X-3 is not the only source to have jets!

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120.17 – The Case for PSR J1614-2230 as a NICER Target

The Neutron star Interior Composition ExploreR (NICER) will launch in 2016 and will spend two years gathering X-ray data on neutron stars and other high-energy sources from a berth on the International Space Station. Its prime scientific goal is to measure the masses and radii of non-accreting neutron stars via fits to the energy-dependent waveforms produced by the rotation of hot spots on their surfaces. These measurements will provide valuable input to theoretical models of cold matter beyond nuclear density. Here we propose that PSR J1614-2230, despite its low count rate, is a promising source to observe with NICER. The reason is that XMM-Newton observations suggest that the fractional oscillation amplitude from PSR J1614-2230 could be high enough that this star cannot be very compact. We show that if we can analyze 0.5 Msec of NICER data and 0.1 Msec of nearby off-source data, and combine that analysis with the known mass of this star, we would find a robust lower limit to the radius with a statistical uncertainty of only 0.5-0.7 km. We also show that even if there is an unmodeled nonthermal component modulated at the pulsation frequency, good statistical fits could rule out significant biases. The low count rate will make reliable upper limits on the radius difficult, but the lower limit could rule out some equations of state that are currently being discussed. This analysis would require a good estimate of the non-source background, so Chandra observations of the vicinity of PSR J1614-2230 would be important.

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120.18 – The Quiescent Neutron Star and Hierarchical Triple, 4U2129+47

4U 2129+47 is a quiescent, eclipsing neutron star that 35 years ago showed typical "Accretion Disk Corona" (ADC) behavior akin to the prototype of the class, X1822-371. Now faded, 4U 2129+47 provides tests of neutron star quiescent emission. It has shown low temperature thermal emission (the neutron star surface), a power law tail (of unknown origin, although possibly due to a pulsar wind interacting with an incoming accretion stream; Campana et al. 1998), and sinusoidally modulated absorption (the disk) as well as periodic X-ray eclipses. Subsequent XMM-Newton and Chandra observations, taken 2007 through Fall 2015, indicate that the hard tail and sinusoidal modulation disappeared, as if the accretion stream and disk have vanished. With the intiial loss of the hard tail, the soft X-ray flux also dropped, but since has remained steady, showing no signs of further neutron star cooling in the subsequent 8 years. We compare this behavior to recent NuSTAR observations of the quiescent neutron star Cen X-4, where the hard tail seems to persist over a wider range of quiescent flux, and correlate with the soft X-ray. It also has been speculated that 4U 2129+47 is part of a hierarchical triple system, with the third body in a much longer orbit. We use the Chandra and XMM-Newton eclipse ephemeris residuals to describe this third body orbit.

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120.19 – The XLF of LMXBs in the fields of early-type galaxies, their metal-rich, and metal-poor globular clusters

The X-ray luminosity function (XLF) of extragalactic low mass X-ray binaries (LMXBs) can provide insights into their nature and origin. We present an analysis of seven early-type galaxies. These galaxies have deep Chandra observations, which detect X-ray sources down to 1037erg/s, and HST optical mosaics that enable the classification of these sources into field LMXBs, globular cluster (GC) LMXBs, and contaminating sources. At all luminosities, we find that the number of field LMXBs per stellar mass is similar in these galaxies. This sample therefore suggests that the GC specific frequency may not influence the field LMXB population. It also suggests that other parameters, such as the stellar IMF, are either similar across the galaxy sample or vary in a way that does not effect the LMXB population. The XLF of the field and GC LMXBs are significantly different (p-value of $3x10^{-6}$), with the latter having a flatter XLF. The XLFs of the metal-rich and metal-poor GC LMXBs are similar, although larger samples will be needed to provide sharper tests in the future.

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120.20 – The Swift Supergiant Fast X-ray Transients outburst factory

We present the Swift Supergiant Fast X-ray Transients project, which has been exploiting Swift's capabilities in a systematic study of SFXTs and classical supergiant X-ray binaries (SGXBs) since 2007. We performed an efficient long-term monitoring of 16 sources including both SFXTs and classical SGXBs and followed source activity across more than 4 orders of magnitude in X-ray luminosity, sampling the light curves on timescales spanning from few hundred seconds to years. We use our measurements of dynamic ranges, duty cycles as a function of luminosity, and luminosity distributions to highlight systematic differences that help discriminate between different theoretical models proposed to explain the differences between the wind accretion processes in SFXTs and classical SGXBs. Our follow-ups of the SFXT outbursts provide a steady advancement in the comprehension of the mechanisms triggering the high X-ray level emission of these sources. In particular, the recent observations of the outburst of the SFXT prototype IGR J17544-2619 on 2014 October 10, when the source reached a peak luminosity of $3x10^{38}$ erg s^{-1}, challenged, for the first time, the maximum theoretical luminosity achievable by a wind-fed neutron star high mass X-ray binary. We propose that this giant outburst was due to the formation of a transient accretion disc around the compact object.

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120.21 – RXTE Observations of Positive Correlations between the Cyclotron Line Parameters and Luminosity in GX 304-1

The Rossi X-ray Timing Explorer observed four outbursts of the accreting X-ray binary transient source GX 304-1 in 2010 and 2011. During the 2010-2011 observations, the HEXTE cluster A viewing direction was fixed aligned with the PCA field of view and HEXTE cluster B was fixed viewing a background region 1.5 degrees off of the source direction. The cluster A background was successfully estimated from cluster B events, and this made possible the measurement of the ~55 keV cyclotron line and an accurate measurement of the continuum. The cyclotron line energy spans 50 to 60 keV throughout each outburst, implying magnetic fields ranging from 4-5 teraGauss as the scattering region reacts to the varying mass accretion rate. We present results of a detailed 3-100 keV spectral analysis of 69 separate observations, and report a greater than 7 sigma measurement of a positive correlation between cyclotron line parameters (energy, width, and depth) and luminosity, as well as other spectral parameters' correlations with luminosity. The three cyclotron line parameters' correlations with luminosity show a flattening of the relationships with increasing luminosity, and have been fitted by quasi-spherical accretion and disk accretion models. The width and depth correlation exponents follow directly from the energy correlation exponent with only the assumption that the accretion column is in the subcritical (Coulomb-braking) regime and the energy changes in proportion to the characteristic stopping length of protons. Correlations of all spectral parameters with primary 2-10 keV power law flux reveal the mass accretion rate to be the primary driver of the spectral shape. A large enhancement in the line of sight column density lasting about three days is seen just before periastron in one outburst and a smaller enhancement of similar duration at the same orbital phase is seen in a second outburst, suggesting the presence of a dense structure in the stellar wind.

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120.22 – Modeling Neutron Star and Galactic Black Hole Emission: The Impact of Proper Extinction Calculations

Interstellar extinction includes both absorption and scattering of photons from interstellar gas and dust grains, and it has the effect of altering a source's spectrum and its total observed intensity. However, while multiple absorption models exist, there are no useful scattering models in standard X-ray spectrum fitting tools, such as XSPEC. Nonetheless, X-ray halos, created by scattering from dust grains, are detected around even moderately absorbed sources and the impact on an observed source spectrum can be significant, if modest, compared to direct absorption. By convolving the scattering cross section with dust models, we have created a spectral model as a function of energy, type of dust, and extraction region that can be used with models of direct absorption. This will ensure the extinction model is consistent and enable direct connections to be made between a source's X-ray spectral fits and its UV/optical extinction. I will present the model and show its impact on a range of Galactic sources including neutron stars and black holes.

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120.23 – X-ray Bursts and Oscillations: Prospects with NICER

X-ray bursts (Type I) are produced by thermonuclear flashes in the accreted surface layers of some neutron stars in Low Mass X-ray Binaries (LMXBs). High frequency oscillations are observed during some of these bursts. These "burst oscillations" result from rotational modulation of an inhomogeneous temperature distribution on the neutron star surface induced by ignition and subsequent spreading of the thermonuclear flash. They provide a means to measure the spin rates of accreting neutron stars and since the burst emission arises from the neutron star surface, a unique probe of neutron star structure. To date, virtually all observations of such oscillations have been made with NASA's Rossi X-ray Timing Explorer (RXTE). We have developed a burst model employing the Schwarzschild + Doppler approximation for surface emission coupled with realistic flame spreading geometries and burst cooling to compute light curves and oscillation amplitudes for both the rising and cooling phases of X-ray bursts. We use this model to explore the capabilities for the Neutron star Interior Composition ExploreR (NICER) to detect and study burst oscillations, particularly in the energy band below 3 keV. NICER is an International Space Station attached payload (X-ray telescope) with capabilities optimized for fast timing of neutron stars in the 0.2–10 keV band. It has large collecting area (twice that of the XMM-Newton EPIC-pn camera), CCD-quality spectral resolution, and high-precision time tagging referenced to UTC through an onboard GPS receiver. NICER will begin its 18-month prime mission around the end of 2016. We will present results of simulated X-ray bursts with NICER that explore its burst oscillation detection capabilities and prospects for inferring neutron star properties from phase-resolved spectra.

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

120.24 – The NuSTAR X-ray Spectrum of Hercules X-1: A Radiation-Dominated Radiative Shock

We report on new spectral modeling of an observation of the accreting X-ray pulsar Her X-1 by the Nuclear Spectroscopic Telescope Array (NuSTAR). We utilize a radiation-dominated radiative shock model that is an implementation of the analytic work of Becker & Wolff (2007) on Comptonized accretion flows onto magnetic neutron stars within the XSPEC analysis environment. We obtain a good fit to the Her X-1 spin-phase averaged 4 to 78 keV X-ray spectrum observed by NuSTAR during a main-on phase of the Her X-1 35-day accretion disk precession period. This model allows us to estimate the accretion rate, the Comptonizing temperature of the radiating plasma, the radius of the magnetic polar cap, and the average scattering opacity parameters in the accretion column. This is in contrast to previous spectral models that characterized the shape of the X-ray spectrum but could not determine the physical parameters of the accretion flow. We describe the details of our spectral fitting model and we discuss the interpretation of the resulting accretion flow physical parameters.

This research is supported by the NASA Astrophysics Data Analysis Program.

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120.25 – Decoding the heartbeat of the microquasar GRS 1915+105: Disk wind Connection

GRS 1915+105 is a microquasar that shows extreme variability in X-ray, IR and radio bands. It shows disk emission, relativistic jets and strong winds during its different states. We observed this source recently with NuSTAR and Chandra during the heartbeat state, characterized a 50 seconds strong oscillations. The oscillations are likely due to thermal/viscous instability in the inner disk when it deviates significantly from the standard Shakura & Sunyaev disk. Combining the high sensitivty of Nustar and the high resolution of Chandra, we use phase spectroscopy to study the details of these oscillation, revealing changes in the inner accretion disk as well as the launching of powerful winds during the oscillations. I will discuss the implications of these results on accretion physics, the thermal instability and the launching mechanism of the wind.

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120.26 – A deep census of the X-ray binary populations in the SMC

The analysis of the deep Chandra survey of the Small Magellanic Cloud (SMC) (a Chandra X-ray Visionary Program) yielded a wealth of discrete X-ray sources down to a limiting luminosity of a few times 10^{32} erg/s. The survey is designed to sample stellar populations of ages between ~10 up to ~100Myr, in order to study the evolution of the X-ray binary populations as a function of age. Based on the comparison of the detected X-ray sources with photometric catalogs of the SMC, we identify over 100 High Mass X-ray binaries (HMXBs) associated with the SMC, 21 of which exhibit pulsations. We measure the formation rate of HMXBs as a function of the age of their parent stellar populations, and we find that it shows a clear peak at ages of ~30-40Myr. In addition we measure the X-ray luminosity function of HMXBs which shows a clear break at a luminosity of ~5×10^{34} erg/s, indicative of the onset of the propeller effect. We discuss these results in the context of X-ray binary populations in environments of different ages and metallicities.

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120.27 – Two methods for studying the X-ray variability

The X-ray aperiodic variability and quasi-periodic oscillation (QPO) are the important tools to study the structure of the accretion flow of X-ray binaries. However, the origin of the complex X-ray variability from X-ray binaries remains yet unsolved. We proposed two methods for studying the X-ray variability. One is amplitude-ratio spectrum analysis method. The other is mapping analysis method. Based on the consideration that the aperiodic variability originates from all spectral components whereas the QPO originates from one spectral component, we divided the root-mean-square (rms) amplitude spectrum of the power density spectrum (PDS) broadband noise component by the amplitude spectrum of an accompanying QPO, and first identified a high-frequency (> 10 Hz) aperiodic variability from the accretion disk (Yan et al. 2013). We now present the evolution of the amplitude-ratio spectrum with the cycle phase of the heartbeat state of the microquasar GRS 1915+105. We produced the energy-frequency-power map to investigate the origin of the X-ray variability, and show that most aperiodic X-ray variability is produced in the corona, and the low-frequency aperiodic variability from the corona is significant in the hard phase of the cycle phase of the heartbeat state of GRS 1915+105 while the low-frequency aperiodic variability from the disk and the corona are both significant in the soft phase.

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Institution(s): *1. Department of Astronomy, Nanjing University, 2. Kapteyn Astronomical Institute, University of Groningen, 3. Purple Mountain Observatory, CAS, 4. Xinjiang Astronomical Observatory, CAS*

120.28 – Are the kHz QPO lags in neutron star 4U 1608-52 due to reverberation?

X-ray reverberation lags have recently been discovered in both active galactic nuclei (AGN) and black hole X-ray binaries. A recent study of the neutron star low-mass X-ray binary 4U 1608-52 has also shown significant lags, whose properties hint at a reverberation origin. Here, we adapt general relativistic ray tracing impulse response functions used to model X-ray reverberation in AGN for neutron star low-mass X-ray binaries, and calculate the expected lags as a function of energy over the range of observed kHz QPO frequencies in 4U 1608-52. We find that the lag energy spectrum is expected to increase with increasing energy above 8 keV, while the observed lags in 4U 1608-52 show the opposite behavior. This demonstrates that the lags in the lower kHz QPO of 4U 1608-52 are not solely due to reverberation. We do note, however, that the models appear to be more consistent with the much flatter lag energy spectrum observed in the upper kHz QPO of several neutron star low-mass X-ray binaries, suggesting that lower and upper kHz QPOs may have different origins.

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

120.29 – Comparison of a third Anomalous Low State with a Normal Low State in LMC X-3 with *MAXI*, *Swift*, and *XMM-Newton*

LMC X-3 is a bright, unusual black hole X-ray binary with high-amplitude, non-periodic long-term variability on the order of hundreds of days, much longer than its 1.7-day orbital period. This long-term variability is believed to be caused by a mass accretion rate change because of an observed lag of the X-rays behind the UV. We have also found LMC X-3 to undergo anomalous low states (ALSs) in which its flux drops dramatically by a factor of about 1000 and stays low for at least 80 days or more. This was last observed in late 2011 into early 2012. LMC X-3 has a rich dataset including observations from JAXA's *MAXI*, NASA's *RXTE* and *Swift*, and as well as ESA's *XMM-Newton*. *MAXI* has continuously monitored the system since 2009 and has excellent coverage of the most recent ALS. *Swift* XRT and UVOT observations have good coverage of LMC X-3's egress into the ALS as well as complete coverage of an additional normal low state. Using these observations we study the behavior of the system as it enters and exits these states in order to quantify the differences in LMC X-3's characteristics during an ALS versus normal low state. The ALS has a minimum flux upper limit of ~0.06 mCrab as measured by *Swift*, while the minimum flux of the normal low state is ~8 mCrab --- more than 130 times brighter. There are also 4 *XMM-Newton* observations that track LMC X-3's entrance into the ALS, with the final observation occurring squarely within the ALS. These data reveal a greater than 7500x drop in flux over that time frame. We model these spectra to measure LMC X-3's spectral evolution into the ALS, and also report what is currently the best measurement we have of the source flux while in an ALS (~0.001 mCrab, which corresponds to less than 2×10^{-5} L_{edd}).

Author(s): Trevor Torpin[1], Patricia T. Boyd3, Alan P. Smale3, Lynne A. Valencic[2]
Institution(s): *1. Catholic University of America, 2. Johns Hopkins University, 3. NASA's Goddard Space Flight Center*

120.30 – The Unusual Long Term Variability of LMXB 4U 1705-440---Fingerprints of Chaotic Evolution?

The bursting Atoll source 4U 1705-44, exhibits high amplitude, long-term aperiodic variability on characteristic timescales of several hundred days. The brightness of the system makes it continuously observable by a variety of all-sky monitors. We combine data from te All-Sky Monitor (ASM) aboard the Rossi X-ray Timing Explorer (RXTE) and MAXI, the Japanese X-ray All-Sky Monitor aboard the International Space Station, resulting in a continuous, uninterrupted, evenly spaced time series containing over fifty cycles at the timescale of interest. We construct a two-dimensional phase space from the flux versus its first derivative, and find a strong resemblence to the canonical double-welled nonlinear Duffing osciallator. We uncover several low-order unstable periodic orbits embedded in the light curve of 4U 1705-44, which imply that the "period-1" orbit lasts ~120 days. We find clear signatures of period-1, period-2 and period-3 orbits and extract these to calculate their topological behavior in phase space. The topoligical relations suggest that the equations describing the long term evolution of 4U 1705-44 are similar to those of the Duffing oscillator. This puts limits on the allowable models describing the longterm variability of 4U 1705-44 and, by extention, to the allowable models describing other systems which show non-periodic superorbital variability.

Author(s): Patricia T. Boyd[2], Rebecca Phillipson[1], Alan P. Smale[2]
Institution(s): *1. Drexel University, 2. NASA's GSFC*

120.31 – The Masses of Black Holes with Wolf-Rayet Companions

Black Holes with Wolf-Rayet companions represent a channel for forming the most massive stellar BHs. The recent, stunning LIGO detection of the gravitational wave signature from a merging stellar BH binary points to the importance of understanding the progenitor systems formation and evolution. The BH+WR binary IC 10 X-1 holds important clues to the puzzle, by helping establish the upper observed BH mass and pointing to an association between maximum possible BH mass and low metallicity environments. However, securing dynamical mass determiniations for WR+BH binaries appears to be complicated by interaction between the radiation field of the BH and the stellar wind. This causes a substantial change to our understanding of IC 10 X-1, and by extension to the mass distribution of BH binaries. A high precision ephemeris derived from a decade of Chandra/XMM X-ray timing observations, when combined with the optical RV curve, reveals a surprizing simultenaity of mid X-ray eclipse and the maximum blueshift velocity of He II emission lines. The optical emission lines appear to originate in a shielded sector of the WR star's stellar wind which escapes total X-ray ionization by the compact object. Unravelling this projection effect is necessary to obtain the system's true mass function. Complementary Chandra, XMM and NuStar datasets offer new insights into the mass and spin of the BH, and the structure of the photo-ionized wind. We will discuss possible routes toward the mass function in BH+WR binaries via multi-wavelength observations, and the additional leverage provided by further constraining the orbital period derivative.

Author(s): Silas Laycock3, James F. Steiner[1], Thomas J. Maccarone[2], Dimitris M. Christodoulou3, Breanna A. Binder4, Jun Yang3, Rigel Cappallo3
Institution(s): *1. MIT Kavli Institute, 2. Texas Tech., 3. University of Massachusetts, 4. University of Washington*

120.32 – Investigating the Long-term Variability of 4U1705-44; Evidence for an Underlying Nonlinear Double-Welled Oscillator

The bright low-mass X-ray binary 4U1705-44 exhibits long-term semi-periodic variability with a timescale of several hundred days. The All-Sky Monitor (ASM) aboard the Rossi X-ray Timing Explorer (RXTE) and the Japanese X-ray All-Sky Monitor (MAXI) aboard the International Space Station together have continuously observed the source from December 1995 through the present. The combined ASM-MAXI data provides a continuous time series over fifty times the length of the timescale of interest. The phase space embedding of the flux versus its first derivative shows a strong resemblance to a double-welled nonlinear oscillator. When comparing our time series against well-known nonlinear oscillators, we find that 4U1705-44 exhibits behavior akin to the Duffing oscillator. Topological analysis can help us identify 'fingerprints' in the phase space of a system unique to its equations of motion. If such 'fingerprints' are the same between two systems, then their equations of motion must be closely related. We therefore found a range of parameters for which the Duffing oscillator closely follows the time evolution of 4U1705-44 and from this range chose 6 different numerical Duffing time series. We can extract low-period, unstable periodic orbits from both the 4U1705-44 and numerical Duffing time series and compare their topological information in phase space, such as their relative rotation rates. We argue that the associated period-1 orbit in 4U1705-44 has a period between 130 and 170 days. The driving periods of our 6 numerical time series correspond to 140 to 175 days. Assigning a logical sequence name to each orbit, the relative rotation rates can be compiled into a unique 'intertwining' matrix. The numerical Duffing time series and the 4U1705-44 intertwining matrices are identical, which provides strong evidence that they share the same underlying template. The implications of this equivalence suggests that we can look to the Duffing equation to describe the X-ray binary's variability.

Author(s): Rebecca Phillipson[1], Patricia T. Boyd[2], Alan P. Smale[2]
Institution(s): *1. Drexel University, 2. NASA Goddard Space Flight Center*

120.33 – Comparing the spatial distributions of HMXBs and star-forming regions in the Small Magellanic Cloud

Initial results are presented comparing the spatial distribution of high-mass X-ray binaries (HMXBs) and massive stellar nurseries (OB associations) in the Small Magellanic Cloud (SMC). The analysis involves constructing the two-point cross-correlation function between pairs of 72 HMXBs and 234 OB associations with the latter being randomly reshuffled following a homogenous distribution, a Gaussian distribution, and a distribution that mimics the star-formation history of the SMC. We find a significant (>5-sigma) correlation between the observed HMXB and OB catalogs compared with a random catalog in which the OB associations are distributed homogeneously across the SMC field. On average, within a kpc of a given HMXB, there are 4 OB associations from the observed catalog for every one from the randomized catalog. There is no significant difference when comparing the HMXBs with the observed catalog versus the random catalog in which the OB distribution traces the star-formation history. This suggests that HMXBs in the SMC have had less time to migrate away from their birthplaces (or, alternatively, that they have a lower average velocity) than HMXBs in the Milky Way. One explanation is that the HMXBs in our sample all host B-emission-line stars that have not yet left the main sequence.

Author(s): Arash Bodaghee3, Vallia Antoniou[2], Andreas Zezas[2], John Tomsick3, Ryan Agnew[1], Eric Frechette[1], Brenton Jackson[1], Zachary Jordan[1]
Institution(s): *1. Georgia College, 2. Harvard CfA, 3. University of California, Berkeley*

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200 – Solar Wind Charge Exchange: Measurements and Models

200.02 – Models of Heliospheric solar wind charge exchange X-ray emission

The first models of the solar wind charge exchange (SWCX) X-ray production in the heliosphere were developed shortly after the discovery of SWCX emission at the end of 1990s. Since then, continuous monitoring of the global solar wind evolution through the solar cycle has allowed better constraints on its interaction with the interstellar neutrals. We have a fairly accurate description of the interstellar neutral density distributions in interplanetary space. However, the solar wind heavy ion fluxes, and especially their short term variability and propagation through interplanetary space, have remained relatively elusive due to the sparseness or lack of in situ data, especially towards high ecliptic latitudes. In this talk, I will present a summary the heliospheric SWCX modeling efforts, and an overview of the global solar cycle variability of heliospheric SWCX emission, while commenting on the difficulties of modeling the real-time variability of the heliospheric X-ray signal.

Author(s): Dimitra Koutroumpa[1]
Institution(s): *1. LATMOS - CNRS - IPSL*

200.03 – Solar Wind Charge Exchange X-ray Emission from Earth's Magnetosheath

The magnetospheric component of solar wind charge-exchange (SWCX) emission is primarily due to interaction between the high-state ions in the solar wind and the hydrogen in the outermost part of the Earth's atmosphere. This emission was the primary source of the ROSAT long-term enhancements (LTEs). Using the correlation between the LTEs and the solar wind flux as well as a dynamic models of the magnetosheath, we have derived the 1/4 keV broad-band charge-exchange cross-section, and can show that this method can not be directly applied to the 3/4 keV band. I will discuss the uncertainties in this method and the prospects for improvement.

Author(s): Steve L Snowden[2], K. D. Kuntz[1]
Institution(s): *1. JHU, 2. NASA/GSFC*

200.04 – DXL: A sounding rocket mission measuring Solar Wind Charge eXchange properties

Solar Wind interacts with the interstellar neutrals via charge exchange mechanism to produce spatially and temporally varying x-rays making it difficult to separate from other diffuse sources. The Diffuse X-rays from the Local Galaxy (DXL) mission measured the spatial signature of Solar Wind Charge eXchange (SWCX) emission due to the helium focusing cone. The mission used 2 large area proportional counters and was able to separate the SWCX contribution from Local Hot Bubble emission. The data from the mission provide a robust estimate of the SWCX contribution to the ROSAT maps, measuring the compound SWCX cross section with He in all ROSAT bands. The results showed that the total SWCX contribution in the ¼ keV band is, on average, ~27%. A new mission, DXL-2, was launched on December 4, 2015 with two new counters for a better understanding of the energy distribution of heliospheric SWCX photons, by using a multi-band approach. A dedicated scan to accurately measure the cone position and solve the IBEX controversy was also performed. The talk will discuss the DXL mission, the results from the first flight, and the preliminary results from the latest flight.

Submitted for the DXL Collaboration

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

200.05 – The temperature and structure of the local hot bubble from DXL mission

DXL (Diffuse X-rays from the Local Galaxy) is a sounding rocket mission designed to quantify and characterize the contribution of Solar Wind Charge eXchange (SWCX) to the diffuse X-ray background. Based on the results from the DXL mission, we estimated the SWCX contribution to the soft X-ray background from the Rosat All Sky Survey (RASS). After removing the SWCX contamination, we were able to measure the temperature and emission measure of the "cleaned" local hot bubble, and to build its 3-Dimensional structure.

Submitted for the DXL Collaboration

Author(s): Wenhao Liu[1]
Institution(s): *1. University of Miami*

200.06 – New Missions and the Future of Solar Wind Charge Exchange Studies

Several newly approved missions in astrophysics and heliophysics will study solar wind charge-exchange (SWCX) directly as either primary or secondary science goals. Of these, SMILE and CuPID will study the magnetosheath by means of the SWCX emission and will provide a direct measure of the magnetospheric emission from in both the 1/4 keV and 3/4 keV bands. HaloSAT observations will be designed to minimize the magnetospheric component for its observations of the Galactic Halo, but will make at least some dedicated observations of heliospheric SWCX. I will outline the simulation needs and observational strategies required to study SWCX for astrophysical purposes.

Author(s): K. D. Kuntz[1]
Institution(s): *1. Johns Hopkins Univ.*

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201 – TeraGauss, Gigatons, and MegaKelvin: Theory and Observations of Accretion Column Physics

201.01 – Overview of the physics in the accretion column

This talk discusses the current efforts to model the wide array of physical processes that are important when plasma accretes onto the surface of a highly magnetic neutron star. Broad non-thermal power law X-ray continua are observed that can be modeled by Comptonization of bremsstrahlung, cyclotron, and black body contributions. Cyclotron resonance absorption lines are observed, cast against these broad continua, yielding measurements of the magnetic field strengths. Observations show that in some sources the cyclotron line energies can vary with observed luminosity. This observation has lead to significant debate regarding aspects of the cyclotron line formation process. Multiple groups are currently working on modeling the physical processes that affect the behavior of the plasmas, the formation of the X-ray continuum, and the formation of the cyclotron lines. New analysis tools are becoming available to help interpret observations of these systems. In particular, observations by Suzaku and NuSTAR of the X-ray spectra of these binary systems are advancing our searches for the cyclotron lines and our understanding of the physical processes that contribute to the X-ray continuum formation.

Author(s): Michael Thomas Wolff[1]
Institution(s): *1. NRL*

201.02 – Application of a physical continuum model to recent X-ray observations of accreting pulsars

We present a uniform spectral analysis in the 0.5-50 keV energy range of a sample of accreting pulsars by applying an empirical broad-band continuum cut-off power-law model. We also apply the newly implemented physical continuum model developed by Becker and Wolff (2007, ApJ 654, 435) to a number of high-luminosity sources. The X-ray spectral formation process in this model consists of the Comptonization of bremsstrahlung, cyclotron, and black body photons emitted by the hot, magnetically channeled, accreting plasma near the neutron star surface. This model describes the spectral formation in high-luminosity accreting pulsars, where the dominant deceleration mechanism is via a radiation-dominated radiative shock. The resulting spectra depend on five physical parameters: the mass accretion rate, the radius of the accretion column, the electron temperature and electron scattering cross-sections inside the column, and the magnetic field strength. The empirical model is fitted to Suzaku data of a sample of high-mass X-ray binaries covering a broad luminosity range (0.3-5 x 10^{37} erg/s). The physical model is fitted to Suzaku data from luminous sources: LMC X-4, Cen X-3, GX 304-1. We compare the results of the two types of modeling and summarize how they can provide new insight into the process of accretion onto magnetized neutron stars.

Author(s): Diana Monica Marcu-Cheatham[7], Katja Pottschmidt[7], Michael Thomas Wolff[4], Peter A. Becker[3], Kent S. Wood[4], Joern Wilms[2], Paul Britton Hemphill[5], Amy Gottlieb[6], Felix Fuerst[1], Fritz-Walter Schwarm[2], Ralf Ballhausen[2]
Institution(s): *1. Caltech, 2. FAU-Erlangen Nuremberg, 3. George Mason University, 4. NRL, 5. UCSD, 6. UFL, 7. UMBC*

201.03 – Physics of Cyclotron Resonance Scattering Features

Cyclotron resonant scattering features (short: cyclotron lines) are sensitive tracers of the physics of the accretion columns and mounds of X-ray pulsars. They form by interaction of X-ray photons with magnetically quantized electrons in the accreted plasma close to the neutron star. Such lines have been observed as absorption-like features for about 20 X-ray pulsars. Their energies provide a direct measure of the magnetic field strength in the line-forming region. By detailed modelling of the lines and of their parameter dependencies we can further decipher the physical conditions in the accretion column. For instance the fact that the complex scattering cross sections have a strong angle-dependence relates the phase-resolved cyclotron line shapes to parameters that constrain the systems' still poorly understood geometry. Modelling the physics of cyclotron lines to a degree that allows for detailed and solid comparison to data therefore provides a unique access also to a better understanding of the overall picture of magnetically accreting neutron star systems.

Author(s): Gabriele Sschoenherr5, Fritz-Walter Schwarm[1], Sebastian Falkner[1], Thomas Dauser[1], Katja Pottschmidt[6], Peter Kretschmar[2], Dmitry Klochkov3, Carlo Ferrigno4, Paul Britton Hemphill7, Joern Wilms[1]
Institution(s): *1. ECAP / FAU Erlangen-Nuremberg, 2. ESA, 3. Institut for Astronomy and Astrophysics, University of Tuebingen, 4. ISDC, 5. Leibniz-Institute for Astrophysics Potsdam (AIP), 6. NASA-GSFC, 7. University of California, San Diego*

201.04 – Spectrum-luminosity dependence of radiation from the polar emitting regions in accreting magnetized neutron stars

The recent progress in observational techniques allowed one to probe the evolution of the X-ray spectrum in accreting pulsars (especially, of the cyclotron absorption line - the key spectral feature of accreting magnetized neutron stars) in great detail on various timescales, from pulse-to-pulse variability to secular trends. Particularly interesting are the discovered spectrum-luminosity correlations which are being used to infer the structure and physical characteristics of the pulsar's polar emitting region. I will present the latest developments in the modeling of the emitting structure (accretion column/mound/spot) aimed at explaining the observed spectrum-luminosity dependences.

Author(s): Dmitry Klochkov[1]
Institution(s): *1. Institut for Astronomy and Astrophysics, University of Tuebingen*

201.05 – Long-term change in the cyclotron line energy in Her X-1

We investigate the long-term evolution in the centroid energy of the Cyclotron Resonance Scattering Feature (CRSF) in the spectrum of the binary X-ray pulsar Her X-1. After the discovery in 1976 by the MPE/AIT balloon telescope HEXE, the line feature was confirmed by several other instruments, establishing the centroid energy at around 35 keV, thereby providing the first direct measure of the B-filed strength of a neutron star at a few 10^12 Gauss. Between 1991 and 1993 an upward jump by ~7 keV occurred, first noted by BATSE and soon confirmed by RXTE and Beppo/SAX. Since then a systematic effort to monitor the cyclotron line energy E_cyc with all available instruments has led to two further discoveries: 1) E_cyc correlates positively with the X-ray luminosity (this feature is now found in four more binary X-ray pulsars). 2) Over the last 20 years the (flux normalized) E_cyc in Her X-1 has decayed by ~5 keV, down to 36.5 keV in August 2015. Her X-1 is the first and so far the only source showing such a variation. We will discuss possible physical scenarios relevant for accretion mounds/columns on highly magnetized neutron stars.

Author(s): Rüdiger Staubert[1]
Institution(s): *1. University of Tübingen*

201.06 – Evidence for an Evolving Cyclotron Line Energy in 4U 1538-522

In this talk, I present results from a comprehensive analysis of the existing RXTE, INTEGRAL, and Suzaku data for the high-mass X-ray binary 4U 1538-522. This persistent X-ray pulsar has a clearly-detected cyclotron resonance scattering feature (CRSF), which appears to have increased in energy over the past decade, from approximately 20-21 keV as measured by RXTE in 1996-2004 to ~22-23 keV as found in the 2012 Suzaku observation. This spectral feature is the only direct measurement of the neutron star's magnetic field strength, and its behavior can be used to track the conditions in the accretion mound near the neutron star surface. Our analysis finds that the increased CRSF energy is especially prominent in spectra from the peak of the main pulse, which suggests that the physical origin of this shift in energy may be restricted to a single magnetic pole, possibly indicating some reconfiguration of the structure of the accretion mound not reflected in the other spectral parameters. I will discuss the analysis and some implications of this result, especially in the context of work by Staubert et al. (2015, A&A 572, 119), which unveiled a secular trend in the CRSF energy of the prototypical CRSF source, Hercules X-1.

Author(s): Paul Britton Hemphill[2], Richard E. Rothschild[2], Felix Fuerst[1], Victoria Grinberg7, Dmitry Klochkov[6], Peter Kretschmar5, Katja Pottschmidt3, Rüdiger Staubert[6], Joern Wilms4
Institution(s): *1. Cahill Center for Astronomy and Astrophysics, California Institute of Technology, 2. Center for Astrophysics and Space Sciences, University of California, San Diego, 3. Center for Space Science and Technology, University of Maryland Baltimore County, 4. Dr. Karl Remeis-Sternwarte & Erlangen Center for Astroparticle Physics, 5. European Space Astronomy Center (ESA/ESAC), 6. Institut für Astronomie und Astrophysik, Universität Tübingen, 7. Kavli Institute for Astrophysics, Massachusetts Institute of Technology*

201.07 – Pulsar observations with *NuSTAR*

The *Nuclear Spectroscopic Telescope Array* (*NuSTAR*) is the first focusing hard X-ray telescope in orbit and ideally suited to study cyclotron lines (CRSFs), due to its good spectral resolution above 10keV and very high signal-to-noise ratio. I will review the results from the first 3 years of *NuSTAR* observations and describe how *NuSTAR* contributes to the discovery and detailed study of CRSFs. *NuSTAR* has discovered a CRSF in KS 1947+319, 4U 1538-22, and 2S 1553-542, increasing the small sample of about 25 known CRSF sources. *NuSTAR* was also responsible for discovering a luminosity dependence of the CRSF energy in Vela X-1 at very low luminosities, as well as measuring an asymmetric line profile for the first time in Cep X-4. I will conclude with a brief outlook into future *NuSTAR* observations and plans.

Author(s): Felix Fuerst[1], MAGNET collaboration[1]
Institution(s): *1. Caltech*

201.08 – Self consistent modeling of accretion columns in accretion powered pulsars

We combine three physical models to self-consistently derive the observed flux and pulse profiles of neutron stars' accretion columns. From the thermal and bulk Comptonization model by Becker & Wolff (2006) we obtain seed photon continua produced in the dense inner regions of the accretion column. In a thin outer layer these seed continua are imprinted with cyclotron resonant scattering features calculated using Monte Carlo simulations. The observed phase and energy dependent flux corresponding to these emission profiles is then calculated, taking relativistic light bending into account. We present simulated pulse profiles and the predicted dependency of the observable X-ray spectrum as a function of pulse phase.

Author(s): Sebastian Falkner3, Fritz-Walter Schwarm3, Michael Thomas Wolff[2], Peter A. Becker[1], Joern Wilms3
Institution(s): *1. George Mason University, 2. Naval Research Laboratory, 3. University of Erlangen-Nuremberg*

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202 – The Structure of the Inner Accretion Flow of Stellar-Mass and Supermassive Black Holes

202.01 – Observations of Relativistically Broadened Iron K-Alpha Lines from AGNs

Relativistic X-ray reflection is commonly seen in many unobscured AGN. The iron K-alpha line is usually its most prominent feature. Observations of broad iron lines from ASCA to NUSTAR will be reviewed and their use in measuring the location and shape of the corona
outlined. They also provide a measure of the spin of the black hole, which is often found to be high. Selection effects involved here will

be discussed.

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

202.02 – Observations of Relativistically Broadened Iron Kalpha Lines From Stellar Mass Black Holes

The measurement of Doppler broadened and gravitationally redshifted iron emission lines from accreting black holes has been used to measure the inner radius of the optically thick disk (Rin). At high mass accretion rates, when the disk is at or close to the Innermost Stable Circular Orbit (ISCO), a determination of Rin provides a constraint on the spin of the black hole. Measuring Rin can also provide information about whether the disk is truncated or not, and this is especially important for understanding the relationship between the disk and the steady jet in the hard state. Over the past few years, the Nuclear Spectroscopic Telescope Array (NuSTAR) has provided improved measurements due to its combination of bandpass (3-79 keV), good energy resolution, and high throughput. In this presentation, we discuss NuSTAR results for a number of stellar mass black holes (e.g., Cyg X-1, GX 339-4, and GRS 1739-278). While these observations have been successful in obtaining measurements of Rin, the improved spectra have also provided extra information about the source geometry and the inner disk inclination, which we will discuss.

Author(s): John Tomsick[1]
Institution(s): *1. UC Berkeley/SSL*

202.03 – Recent X-ray Reverberation Mapping Results

In recent years, X-ray reverberation has opened a new way to investigate the inner accretion flow around black holes. XMM-Newton and NuSTAR observations of the high-frequency variability have shown that the soft excess, broad iron K line and Compton hump lag behind the continuum emission, suggesting light travel distances of a few gravitational radii. Beyond simply detecting reverberation, we are beginning to use reverberation to map out the geometry of the inner accretion flow, testing the compactness of the X-ray emitting source, the structure of the disc and the origin of the variability. In this talk, I will give an overview of the observational results discovered thus far, and will discuss future prospects for reverberation with upcoming observations and telescopes.

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

202.04 – Modeling the Compton Hump Reverberation Observed in Active Galactic Nuclei

In recent years, observations of the Iron K alpha reverberation in supermassive black holes have provided a new way to probe the inner accretion flow. Furthermore, a time lag between the direct coronal emission and the reprocessed emission forming the Compton Hump in AGN has been observed. In order to model this Compton Hump reverberation we performed general relativistic ray tracing studies of the accretion disk surrounding supermassive black holes, taking into account both the radial and angular dependence of the ionization parameter. We are able to model emission not only from a lamp-post corona but also implementing 3D corona geometries. Using these results we are able to model the observed data to gain additional insight into the geometry of the corona and the structure of the inner accretion disk.

Author(s): Janie Hoormann[1], Banafsheh Beheshtipour[1], Henric Krawczynski[1]
Institution(s): *1. Washington University in St. Louis*

202.05 – Global simulations of sub- and super-Eddington black hole accretion disks in general relativity

In this talk I will review the recent progress in simulating optically thick black hole accretion flows. I will briefly describe the computational methods and present simulations of both sub- and super-Eddington accretion disks. The properties of such flows will be described in detail and compared with observed characteristics of ULXs and X-ray binaries. I will also address the question of thermal stability of radiatively efficient accretion disks.

Author(s): Aleksander Sadowski[1]
Institution(s): *1. MIT*

202.06 – X-ray Spectra from GRMHD Simulations of Accreting Black Holes

We present the results of a global radiation transport code coupled to general relativistic magnetohydrodynamic (GRMHD) simulations of accreting black holes. For the first time, we are able to explain from first principles in a self-consistent way all the components seen in the X-ray spectra of stellar-mass black holes, including a thermal peak and all the features associated with strong hard X-ray emission: a power law extending to high energies, a Compton reflection hump, and a broad iron line. Varying only the mass accretion rate, we are able to reproduce a wide range of X-ray states seen in most galactic black hole sources. The temperature in the corona is $T_e \sim 10$ keV in a boundary layer near the disk and rises smoothly to $T_e >\sim 100$ keV in low-density regions far above the disk. We self-consistently solve for the ionization state of gas in each vertical column of the disk, in turn giving iron fluorescent emissivity profile.

Author(s): Jeremy Schnittman[2], Scott Noble3, Julian H. Krolik[1], Brooks Kinch[1]
Institution(s): *1. Johns Hopkins University, 2. NASA/GSFC, 3. University of Tulsa*

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203 – Missing Baryons and the Hot Halo of the Milky Way

203.01 – Missing metals and baryons in galaxies: Clues from our Milky Way

It is well-known that most galaxies are missing most of their baryonic mass. Perhaps more surprisingly, they also seem to be missing most of their metals. Our Milky Way galaxy, like other nearby galaxies, is missing most of its baryons. Cosmological simulations of galaxy formation suggest that the missing baryonic mass should reside in the circum-galactic medium (CGM), in a warm-hot gas phase at temperatures between one million and 10 million K. Although theoretical models predict the existence of the warm-hot gas in the CGM, detecting and characterizing the diffuse CGM has been difficult. At the expected temperatures the baryons are in the form of highly ionized plasma, observable in soft X-rays. A combination of absorption and emission studies at soft X-ray energies is required to fully characterize this warm-hot CGM. Recently, combining the Chandra observations of OVII and OVIII absorption lines and XMM-Newton and Suzaku measurements of the Galactic halo emission measure, we found that there is a huge reservoir of ionized gas around the Milky Way, with the mass of over 2 billion solar masses and the radius of over 100 kpc.

I will present Chandra, XMM-Newton and Suzaku observations probing our Milky Way halo in absorption and emission. Our results show that the Milky Way halo contains a huge reservoir of warm-hot gas that may account for a large fraction of missing baryons and metals. I'll review current status of this field, discuss implications of our results to models of galaxy formation and evolution and outline paths for future progress.

Author(s): Anjali Gupta[1]
Institution(s): *1. Columbus State*

203.02 – X-ray absorption/emission line spectroscopy of the Galactic hot gaseous halo

There is an ongoing debate as to whether or not the Milky Way is surrounded by a large-scale, massive corona. Vastly different conclusions as to its extent and mass have been drawn from existing studies based on X-ray absorption and/or emission line spectroscopy. I will discuss my assessment of this issue, focusing

on various uncertainties and potential problems in the present data, analyses, results, and interpretations.
In particular, I will examine how different assumptions about the temperature distribution of the corona affect the inference of its physical scale. I will also discuss the external perspectives of galactic coronae obtained form observing nearby highly-inclined disk galaxies.

Author(s): Daniel Wang[1]
Institution(s): *1. University of Massachusetts*

203.03 – The Crossroads between the Galactic Disk and Interstellar Space, Ablaze in 3/4 keV Light

The halo is the crossroads between the Galactic disk and intergalactic space. This region is inhabited by hot gas that has risen from the disk, gas heated in situ, and hot material that has fallen in from intergalactic space. Owing to high spectral resolution observations made by by XMM-Newton, Suzaku, and Chandra of the hot plasma's 3/4 keV emission and absorption, increasingly sophisticated and CPU intensive computer modeling, and an awareness that charge exchange can contaminate 3/4 keV observations, we are now better able to understand the hot halo gas than ever before.
Spectral analyses indicate that the 3/4 keV emission comes from T ~ 2.2 million Kelvin gas. Although observations suggest that the gas may be convectively unstable and the spectra's temperature is similar to that predicted by recent sophisticated models of the galactic fountain, the observed emission measure is significantly brighter than that predicted by fountain models. This brightness disparity presents us with another type of crossroads: should we continue down the road of adding physics to already sophisticated modeling or should we seek out other sources? In this presentation, I will discuss the galactic fountain crossroads, note the latitudinal and longitudinal distribution of the hot halo gas, provide an update on charge exchange, and explain how shadowing observations have helped to fine tune our understanding of the hot gas.

Author(s): Robin L. Shelton[1]
Institution(s): *1. Univ. of Georgia*

203.04 – A Rotation Signature in the Hot Halo of the Milky Way

The hot halo of the Milky Way is massive and dynamically important to the evolution of the Galaxy over cosmic time, so it is important to constrain its basic thermal, chemical, and structural properties. The kinematic structure remains unknown, so we measured the centroids of local OVII(r) absorbers seen towards background quasars in XMM-Newton Reflection Grating Spectrometer data and compared them to simple models for bulk halo motion. The data rule out a stationary halo and suggest a scenario in which the halo gas rotates at about 150 km/s in the prograde direction, at least within 50 kpc of the Sun. We also measured an inflow/outflow velocity consistent with zero.

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

203.05 – 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 will describe the HaloSat mission concept, progress towards its implementation, and plans for archiving and distribution of the data.

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

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205 – Plenary Talk: Observation of Gravitational Waves in Advanced LIGO, Laura Cadonati (Georgia Tech)

205.01 – Observation of Gravitational Waves in Advanced LIGO

One hundred years after Einstein's formulation of General Relativity, LIGO has observed gravitational waves from a binary black hole merger. In this talk I will present this groundbreaking discovery, which took place during the first observing run of Advanced LIGO, and its implications for a new gravitational wave astronomy.

Author(s): Laura Cadonati[1]
Institution(s): *1. Georgia Tech*

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206 – Early Results from the Astro-H Mission

206.01 – The ASTRO-H X-ray Observatory

ASTRO-H, the new Japanese X-ray Astronomy Satellite following Suzaku, is an international X-ray mission, planed for launch in Feb, 2016. ASTRO-H is a combination of high energy-resolution soft X-ray spectroscopy (0.3 - 10 keV) provided by thin-foil X-ray optics and a micro-calorimeter array, and wide band X-ray spectroscopy (3 - 80 keV) provided by focusing hard X-ray mirrors and hard X-ray imaging detectors. Imaging spectroscopy of extended sources by the micro-calorimeter with spectral resolution of <7 eV can reveal line broadening and Doppler shifts due to turbulent or bulk velocities. The mission will also carry an X-ray CCD camera as a focal plane detector for a soft X-ray telescope and a non-focusing soft gamma-ray detector based on a narrow-FOV semiconductor Compton Camera. With these instruments, ASTRO-H covers very wide energy range from 0.3 keV to 600 keV. The simultaneous broad band pass, coupled with high spectral resolution by the micro-calorimeter will enable a wide variety of important science themes to be pursued.
The ASTRO-H mission objectives are to study the evolution of yet-unknown obscured super massive Black Holes in Active Galactic Nuclei; trace the growth history of the largest structures in the Universe; provide insights into the behavior of material in extreme gravitational fields; trace particle acceleration structures in clusters of galaxies and SNRs; and investigate the detailed physics of jets.
ASTRO-H will be launched into a circular orbit with altitude of about 575 km, and inclination of 31 degrees.
ASTRO-H is in many ways similar to Suzaku in terms of orbit, pointing, and tracking capabilities. After we launch the satellite, the current plan is to use the first three months for check-out and start the PV phase with observations proprietary to the ASTRO-H team. Guest observing time will start from about 10 months after the launch. About 75 % of the satellite time will be devoted to GO observations after the PV phase is completed.
In this presentation, we will describe the mission, scientific goal and report the initial performance on the orbit.

Author(s): Tadayuki Takahashi[1]
Institution(s): *1. ISAS/JAXA*

206.02 – Progress report on the Astro-H Soft X-Ray Spectrometer

We describe the initial in-orbit operations and performance of the Astro-H Soft X-Ray Spectrometer (SXS). Astro-H, JAXA's sixth X-ray observatory, is scheduled for launch on February 12, 2016, from the Tanegashima Space Center in Japan abord an H-IIA rocket. The instrument is based on a 36-pixel array of microcalorimeters designed for high resolution over the 0.3-12 keV energy band at the focus of a high throughput, grazing-incidence x-ray mirror. The instrument is the result of a joint collaboration between the JAXA Institute of Space and Astronautical Science and many partners in Japan, and the NASA/Goddard Space Flight Center and collaborators in the US. The principal components of the spectrometer are the microcalorimeter detector system, a low-temperature anticoincidence detector, a 3-stage adiabatic demagnetization refrigerator (ADR) to maintain 50 mK operation under both cryogen and cryogen-free operation, a hybrid liquid helium/cryogen-free dewar with both Stirling and Joule-Thomson coolers, electronics for reading out the array, processing the x-ray data for spectroscopy, and operating the ADR and cryocoolers. The dewar is closed out by an aperture system with five thin-film filters designed to provide high x-ray transmission with low heat loads to the dewar and detector system, and prevent contamination from condensing on the filters. The instrument was designed to have better than 7 eV energy resolution, and was demonstrated to achieve 4-5 eV resolution across the array at the full spacecraft level of integration during extensive ground testing prior to launch. The overall cooling chain has been designed to provide a lifetime of at least 3 years in orbit, and continue to operate without liquid helium to provide redundancy and the longest operational lifetime for the instrument. In this presentation, we will describe the early phases of the SXS instrument in orbit and provide a sense of the astronomical results that can be expected.

This presentation is being given on behalf of the very large international team that developed this complex instrument.

Author(s): Richard L. Kelley[2], Kazuhisa Mitsuda[1]
Institution(s): *1. JAXA Institute of Space and Astronautical Science, 2. NASA's GSFC*

206.03 – *ASTRO-H* Guest Observer Program

ASTRO-H is a powerful new X-ray observatory for the community: starting approximately 9 month after launch, the bulk of the observing time will belong to guest observers (GOs) to be allocated via an international Guest Observer program. For US-based observers, the first call for proposals is a part of ROSES-2016, while there are parallel calls for proposals by ESA for European astronomers, and by ISAS/JAXA for the Japanese community and all other researchers not in the US or in an ESA member country.

We will present the parameters of the Cycle 1 Call for Proposals, concentrating on US-specific details as appropriate. We will discuss the international division of observing time, the relationship with the on-going performance verification (PV) phase observations, our expectation for the number of US targets to be accepted and the financial support that will be available, and the timeline including the proposal deadline and expected period of Cycle 1 observations

Author(s): Koji Mukai[2], Robert Petre[1]
Institution(s): *1. NASA/GSFC, 2. UMBC and NASA/GSFC /CRESST*

207 – Stellar Compact II

207.01 – High-Energy Emission at Shocks in Millisecond Pulsar Binaries

A large number of new Black Widow (BW) and Redback (RB) energetic millisecond pulsars have been discovered through radio searches of unidentified Fermi sources, increasing the known number of these systems from 4 to 28. We model the high-energy emission components from particles accelerated to several TeV in intrabinary shocks in BW and RB systems, and their predicted modulation at the binary orbital period. Synchrotron emission is expected at X-ray energies and such modulated emission has already been detected by Chandra and XMM. Inverse Compton emission from accelerated particles scattering the UV emission from the radiated companion star is expected in the Fermi and TeV bands. Detections or constraints on this emission will probe the unknown physics of pulsar winds.

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

207.02 – Quasisoft X-ray Sources: their physical natures revealed

Quasisoft X-ray sources (QSSs) have been the Mona Lisa of X-ray sources. They have remained enigmatic, even though we have known of their existence and basic properties for more than a decade. QSSs have X-ray luminosities greater than 10^{36} erg/s, but emit few or no photons above 2 keV. They were discovered in external galaxies during searches for softer sources, supersoft X-ray sources (SSSs). Every external galaxy contains QSSs, but it has been challenging to find any in the Milky Way and the Magellanic Clouds. Recent work, however, reveals that a significant fraction of QSSs may be black holes. We review what is known about QSSs to date, because this obscure class of objects may at last to be ready for "prime time", capable of identifying BHs in a wide range of Galactic environments.

Author(s): Rosanne Di Stefano[1], Francis A. Primini[1], Jincheng Guo[1], Jifeng Liu[2]
Institution(s): *1. Harvard-Smithsonian CfA, 2. National Astronomical Observatory of China*

207.03 – *Chandra* and *NuSTAR* studies of the ultraluminous X-ray sources in M82

With the discovery of the ultraluminous X-ray pulsar in M82 by Bachetti et al (2014), there has been renewed interest in the galaxy, which also hosts one of the best candidates for an intermediate-mass black hole. We present results on the spectral and temporal properties of the pulsar from 15 years of *Chandra* observations with implications for theoretical modeling of the source, as well as the high-energy constraints on both sources from *NuSTAR*.

Author(s): Murray Brightman[1], Fiona Harrison[1], Dom Walton3, Felix Fuerst[1], Matteo Bachetti[2], Andreas Zezas5, Andrew Ptak4, Ann E. Hornschemeier4, Mihoko Yukita4, Shriharsh P. Tendulkar[1], Brian Grefenstette[1]
Institution(s): *1. California Institute of Technology, 2. INAF/Osservatorio Astronomico di Cagliari, 3. Jet Propulsion Laboratory, 4. NASA Goddard Space Flight Center, 5. University of Crete*

207.04 – Probing the clumpy winds of giant stars with high mass X-ray binaries

Line-driven winds from early type stars are structured, with small, overdense clumps embedded in tenuous hot gas. High mass X-ray binaries (HMXBs), systems where a neutron star or a black hole accretes from the line-driven stellar wind of an O/B-type companion, are ideal for studying such winds: the wind drives the accretion onto the compact object and thus the X-ray production. The radiation from close to the compact object is quasi-pointlike and effectively X-rays the wind.

We used RXTE and Chandra-HETG observations of two of the brightest HMXBs, Cyg X-1 and Vela X-1, to decipher their wind structure. In Cyg X-1, we show that the orbital variability of absorption can be only explained by a clumpy wind model and constrain the porosity of the wind as well as the onion-like structure of the clumps. In Vela X-1 we show, using the newest reference energies for low ionization Si-lines obtained with LLNL's EBIT-I, that the ionized phase of the circumstellar medium and the cold clumps have different velocities.

Author(s): Victoria Grinberg[2], Natalie Hell4, Maria Hirsch4, Javier Garcia[1], David Huenemoerder[2], Maurice A. Leutenegger3, Michael Nowak[2], Katja Pottschmidt3, Norbert S. Schulz[2], Jon O. Sundqvists[6], Richard D. Townsend5, Joern Wilms4
Institution(s): *1. Harvard/CfA, 2. Massachusetts Institute of Technology, Kavli Institute for Astrophysics, 3. NASA/GSFC, 4. Remeis Observatory/ECAP/FAU, 5. Univ. of Wisconsin-Madison, 6. University of Delaware*

207.05 – A NICER Look at Accreting Stellar Black Holes

We present an overview of NICER's far-reaching observational capabilities for accreting stellar-mass black holes. NICER's high throughput, large collecting area, and sensitivity at low energies will afford an unprecedented view of black holes across all states. Black hole spectral-timing states are traversed when a black hole evolves through its outburst cycle, and each state is comprised of thermal disk, Compton, and reflection components. Crucially, NICER will produce our first direct look at oscillations in the thermal disk itself. Never before has the thermal peak of the accretion disk been easily accessible in the time domain. NICER spectra will impose strong constraints on the spectrum of thermal seed photons and the shape of the Compton component at low energies. In addition, NICER will produce reverberation maps of stellar-mass black holes in each of the thermal, Compton, and Fe-K (reflection) bands. Such data will be particularly critical for linking models of spectral reflection to Comptonization. At the same time, quasi-periodic X-ray oscillations from the thermal disk may yield precise signatures of a black-hole's spin and would be readily detectable with NICER. NICER data will demand a next generation of self-consistent models and push forward our understanding of the intricate interplay between Compton, thermal, and reflection components.

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

207.06 – A Luminous High-Mass Gamma-ray Binary in the Large Magellanic Cloud

We have been undertaking a search for gamma-ray binaries from the detection of periodic modulation in light curves from all sources in the Fermi LAT 3FGL catalog. From this search we identified a 10 day modulation in the direction of the LMC. A localization of the modulation indicates that it arises from a point source identified in a recent Fermi-LAT survey of the LMC. The nature and identification of this source had been uncertain. We find that the counterpart is a previously reported candidate high-mass X-ray binary with an O6III(f) primary located in a supernova remnant. Swift XRT observations of this source show modulation on the 10 day gamma-ray period, but with a different epoch of maximum flux. ATCA radio observations (5.5 and 9 GHz) also reveal variable radio emission from this source. Optical spectroscopy (SAAO and SOAR) show that while there are no large changes in the spectrum, there is apparent radial velocity modulation. At all wavebands this new gamma-ray binary is significantly more luminous than comparable Galactic systems, even though very few of these are known. The discovery of this extragalactic gamma-ray binary may have implications for the overall population of gamma-ray binaries and their evolutionary pathways and lifetimes.

Author(s): Robin Corbet[9], Chi C. Cheung[6], Laura Chomiuk[4], Malcolm J. Coe[7], Joel Barry Coley[5], Guillaume Dubus[2], Philip Edwards[1], Pierrick Martin[3], Vanessa McBride[8], Jamie Stevens[1], Jay Strader[4], Lee Townsend[8]
Institution(s): *1. CSIRO, 2. Grenoble , 3. IRAP, 4. MSU, 5. NASA GSFC, 6. NRL, 7. Southampton University, 8. UCT, 9. UMBC*

300 – The Physics of Accretion Disks – A Joint HEAD/LAD Session

300.01 – The theory of accretion disks - insights from local and global simulations

In this brief review, I summarize the key physical processes that are believed to operate in accretion disks. To understand each of these processes, e.g., the angular transport that is facilitated by the so-called magneto-rotational instability or large scale outflow, as well as their interplay, one has to use numerical simulations to gain insights into the time-dependent, multi-dimensional and -scale nature of accretion disks. Therefore, I also present some results of most recent local and global numerical simulations.

Author(s): Daniel Proga[1]
Institution(s): *1. Univ. Of Nevada, Las Vegas*

300.02 – Black holes in the lab: A review of accretion experiments using plasmas and liquid metals

In this talk, we will survey recent liquid metal and plasma experiments attempting to study the magnetorotational instability, and ultimately, turbulent transport of angular momentum in laboratory plasmas that can mimic the Keplerian velocity profiles of accretion disks. We will describe the basic requirements of such experiments, the techniques used to create such laboratory experiments, and then review the results obtained thus far. The experiments fall into two camps, the first of which use resisitve liquid metal in couette flow geometry, and the second of which uses confined plasma that is stirred by induction on the plasma boundary. The regimes covered by liquid metals are compimentary: liquid metals are very resistive but nearly inviscid and may be appropriate for modeling protostellar disks, while hot plasmas are more viscous than resisitve and may be appropriate for hot accretion disks around black holes. Both approaches have overcome major experimental hurdles and now have dimensionless parameters that are in a regime where the MRI should be observed.

Author(s): Cary Forest[1]
Institution(s): *1. University of Wisconsin, Madison*

300.03 – Recent Observational Progress on Accretion Disks Around Compact Objects

Studies of accretion disks around black holes and neutron stars over the last ten years have made remarkable progress. Our understanding of disk evolution as a function of mass accretion rate is pushing toward a consensus on thin/thick disk transitions; an apparent switching between disk-driven outflow modes has emerged; and monitoring observations have revealed complex spectral energy distributions wherein disk reprocessing must be important. Detailed studies of disk winds, in particular, have the potential to reveal the basic physical processes that mediate disk accretion, and to connect with numerical simulations. This talk will review these developments and look ahead to the potential of Astro-H.

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

301 – Gravitational Waves

301.01 – Status of Advanced LIGO

The two advanced detectors of the Laser Gravitational Wave Observatory (LIGO) recently completed their first Observing run O1. Targeting a factor of 10 sensitivity improvement over initial detectors, Advanced LIGO promises to open the new era of gravitational wave astronomy. Even if not yet operating at full sensitivity, with O1 Advanced LIGO has already largely surpassed the space-time volume surveyed by previous observations. This talk describes the Advanced LIGO detectors, their current sensitivity performance, and future prospects.

Author(s): Lisa Barsotti[1]
Institution(s): *1. MIT*

301.02 – Fermi GBM Counterparts to LIGO Gravitational-Wave Candidates

As the advanced configuration of the Laser Interferometer Gravitational-wave Observatory has begun operations, we eagerly anticipate the detection of gravitational waves (GW) with LIGO in coincidence with a gamma-ray signal from the Fermi Gamma-ray Burst Monitor (GBM). The most likely source is a short Gamma-Ray Burst (GRB) arising from the merger of two compact objects. With its broad sky coverage, GBM triggers and localizes more short GRBs than other active space missions, ~40 each year.

Combining GBM and LIGO localization uncertainty regions may provide a smaller target to look for the GW host. A joint GBM-LIGO detection increases the confidence in the GW detection and helps characterize the parameters of the merger. Offline searches for weak GRBs that fail to trigger onboard Fermi indicate that additional short GRBs can be detected in the GBM data. I will discuss the implementation and expected benefits of joint searches to detect and localize GW candidates. I will also explore how the non-detection in the GBM data of a signal consistent with GW candidates in the LIGO data can affect follow-up strategies for counterpart searches by other observers.

Author(s): Eric Burns5, Lindy Blackburn[2], Michael Stephen Briggs5, Jordan Camp3, Nelson Christensen[1], Valerie Connaughton[8], Adam Goldstein4, Tyson Littenberg[8], Judith L. Racusin3, Peter S. Shawhan7, Leo Pound Singer3, John Veitch[6], Binbin Zhang5
Institution(s): *1. Carleton College, 2. Harvard–Smithsonian Center for Astrophysics, 3. NASA/GSFC, 4. NASA/MSFC, 5. University of Alabama in Huntsville, 6. University of Birmingham, 7. University of Maryland, 8. USRA*

301.03 – LISA Pathfinder and the road to space-based detection of gravitational waves

The LISA Pathfinder spacecraft was launched on Dec 3rd, 2015 and began science operations in March 2016. Led by the European Space Agency with contributions from a number of European national agencies, universities, and NASA, LISA Pathfinder will demonstrate several key technologies and measurement technqiues for future space-based gravitational wave observatories. A successful LISA Pathfinder will retire much of the technical risk for such missions, which are the only proposed instruments capable of observing gravitational waves in the milliHertz band, a source-rich region expected to include singals from merging extragalactic massive black holes, capture of stellar-mass compact objects by massive black holes, and millions of individual close compact binaries in the Milky Way. I will present an overview of the LISA Pathfinder mission, it's current status, and the plans for operations and data analysis.

Author(s): James Thorpe[1]
Institution(s): *1. NASA GSFC*

301.04 – Bringing Black Holes Together: How Supermassive Black Hole Binaries Form and Plunge Through the Final Parsec

Astronomers now know that supermassive black holes reside in nearly every galaxy.
Though these black holes are an observational certainty, nearly every aspect of their evolution -- from their birth, to their fuel source, to their basic dynamics -- is a matter of lively debate. In principle, gas-rich major galaxy mergers can generate the central stockpile of fuel needed for a low mass central black hole seed to grow quickly into a supermassive one. During a galaxy merger, the black holes in each galaxy meet and form a supermassive binary black hole; as the binary orbit shrinks through its final parsec, it becomes the loudest gravitational wave source in the Universe and a powerful agent to sculpt the galactic center. This talk will touch on some current and ongoing work on refining our theories of how supermassive black hole binaries form, evolve within, and alter their galaxy host.

Author(s): Kelly Holley-Bockelmann[1]
Institution(s): *1. Vanderbilt University*

301.05 – ESA's L3 mission: A space-based gravitational-wave observatory

ESA selected the Gravitational Universe as the science theme for one of its future L-class missions. L3 will measure gravitational waves in the 10μHz to 100mHz window; probably the richest of all gravitational wave windows. Expected sources in this frequency band range from massive black hole mergers to extreme mass ratio inspirals to compact galactic binary systems.
The L3 mission is expected to be based on the eLISA/LISA design which was submitted by the eLISA consortium as a notional mission concept. NASA started discussions with ESA how to join L3 and participates in ESA's Gravitational Observatory Advisory Team. NASA is also in the process of setting up its own L3-Study team to look at potential US contributions to L3. This group will also act as the US partner for the eLISA consortium. In summary, the space component of the GW community has gained significant momentum over the last 12 months and a successful pathfinder mission and potential GW discoveries by Advanced LIGO and/or pulsar timing arrays should further strengthen the case for LISA.

Author(s): Guido Mueller[1]
Institution(s): *1. University of Florida*

302 – Missions & Instruments

302.01 – NICER: Mission Overview and Status

NASA's Neutron star Interior Composition Explorer (NICER) mission will explore the structure, dynamics, and energetics of neutron stars through soft X-ray (0.2–12 keV) timing and spectroscopy. An external attached payload on the International Space Station (ISS), NICER is manifested on the Commercial Resupply Services SpaceX-11 flight, with launch scheduled for late 2016. The NICER payload is currently in final integration and environmental testing. Ground calibration has provided robust performance measures of the optical and detector subsystems, demonstrating that the instrument meets or surpasses its effective area, timing resolution, energy resolution, etc., requirements. We briefly describe the NICER hardware, its continuing testing, operations and environment on ISS, and the objectives of NICER's prime mission—including precise radius measurements for a handful of neutron stars to constrain the equation of state of cold, ultra-dense matter. Other contributions at this meeting address specific scientific investigations that are enabled by NICER, for neutron stars in their diverse manifestations as well as for broader X-ray astrophysics through a brief, approved Guest Observer program beginning in 2018.

Author(s): Zaven Arzoumanian[2], Keith C. Gendreau[1]
Institution(s): *1. NASA/GSFC, 2. Universities Space Research Association*

302.02 – Observatory Science with the NICER X-ray Timing Instrument

This presentation is submitted on behalf of the NICER Observatory Science Working Group. NICER will be deployed on the International Space Station later in 2016. The X-ray sensitivity spans 0.2-12 keV, with CCD-like spectral resolution, low background rates, and unprecedented timing accuracy. A Guest Observer (GO) Program has been approved by NASA as one of the proposed Science Enhancement Options, contingent on NICER meeting its Prime Mission Science Objectives. The NICER Science team will observe limited Observatory Science targets (i.e., sources other than neutron stars) in year 1, and GO observations will constitute 50% of the exposures in year 2. Thereafter, NICER will compete for continuation via the NASA Senior Review process. NICER Instrument performance is compared with Missions such as XMM-Newton and RXTE. We briefly highlight the expected themes for Observatory Science relating to accreting black holes on all mass scales, magnetic CVs, active stars, and clusters of galaxies.

Author(s): Ronald A. Remillard[1]
Institution(s): *1. MIT*

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

We present the scientific motivation and performance for Arcus, an X-ray grating spectrometer mission to be proposed to NASA as a MIDEX in 2016. This mission will observe structure formation at and beyond the edges of clusters and galaxies, feedback from supermassive black holes, the structure of the interstellar medium and the formation and evolution of stars. Key mission design parameters are R = 3000 with >500 cm2 of effective area at the crucial O VII and O VIII lines, with the full bandpass going from ~10-50 Angstroms. Arcus will use the silicon pore optics developed for ESA's Athena mission, paired with off-plane gratings being developed at the University of Iowa and combined with MIT/Lincoln Labs CCDs. With essentially no consumables, Arcus should achieve its mission goals in under 2 years, after which we anticipate a substantial period of operation as a general observatory.

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

302.04 – MeV Science with the Advanced Energetic Pair Telescope (AdEPT), a High Sensitivity Medium-Energy Gamma-Ray Polarimeter

Many high-energy astrophysical phenomena exhibit unique, transitory behavior, such as spectral breaks, bursts, and flares below ~200 MeV. However, while significant progress in gamma-rays has been made by instruments such as Fermi and AGILE, a significant sensitivity gap remains in the medium-energy regime (0.75 - 200 MeV) that has been explored only by COMPTEL and EGRET on CGRO. Tapping into this unexplored regime requires development of a telescope with significant improvement in sensitivity. Our mission concept, covering ~5 to ~200 MeV, is the Advanced Energetic Pair Telescope (AdEPT). The AdEPT telescope will achieve angular resolution of ~0.6 deg at 70 MeV, similar to the angular resolution of Fermi/LAT at ~1 GeV that brought tremendous success in identifying new sources. AdEPT will also provide unprecedented polarization sensitivity, ~1% for a 1 Crab source. The enabling technology for AdEPT is the Three-Dimensional Track Imager (3-DTI) a low-density, large volume, gas time-projection chamber with a 2-dimensional readout. The 3-DTI provides high-resolution three-dimensional electron tracking with minimal Coulomb scattering that is essential to achieve high angular resolution and polarization sensitivity. We describe the design, fabrication, and performance of the 3-DTI detector, describe the development of a 50x50x100 cm3 AdEPT prototype, and highlight a few of the key science questions that AdEPT will address.

Author(s): Tonia M. Venters[1], Stanley D. Hunter[1], Georgia De Nolfo[1], Andrei R Hanu[1], John F Krizmanic[1], Floyd W. Stecker[1], Andrey Timokhin[1]
Institution(s): *1. Goddard Space Flight Center*

302.05 – AdEPT, the Advanced Energetic Pair Telescope for Medium-Energy Gamma-Ray Polarimetry

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

Author(s): Stanley D. Hunter[1]
Institution(s): *1. NASA/GSFC*

302.06 – Large Observatory For X-ray Timing (LOFT-P): A Probe-Class Mission Concept

LOFT-P is a mission concept for a NASA Astrophysics Probe-Class (<$1B) X-ray timing mission, based on the LOFT M-class concept originally proposed to ESA's M3 and M4 calls. LOFT-P requires very large collecting area, high time resolution, good spectral resolution,broadband spectral coverage (2-30 keV), highly flexible scheduling, and an ability to detect and respond promptly to time-critical targets of opportunity. It addresses science questions such as: What is the equation of state of ultra dense matter? What are the effects of strong gravity on matter spiraling into black holes? It would be optimized for sub-millisecond timing of bright Galactic X-ray sources including X-ray bursters, black hole binaries, and magnetars to study phenomena at the natural timescales of neutron star surfaces and black hole event horizons and to measure mass and spin of black holes. These measurements are synergistic to imaging and high-resolution spectroscopy instruments, addressing much smaller distance scales than are possible without very long baseline X-ray interferometry, and using complementary techniques to address the geometry and dynamics of emission regions. LOFT-P would have an effective area of >6 m^2, >10x that of the highly successful Rossi X-ray Timing Explorer (RXTE). A sky monitor (~2-50 keV) acts as a trigger for pointed observations, providing high duty cycle, high time resolution monitoring of the X-ray sky with ~20 times the sensitivity of the RXTE All-Sky Monitor, enabling multi-wavelength and multi-messenger studies. A probe-class mission concept would employ lightweight collimator technology and large-area solid-state detectors, segmented into pixels or strips, technologies which have been recently greatly advanced during the ESA M-3 Phase A study of LOFT. Given the large community interested in LOFT (>800 supporters), the scientific productivity of this mission is expected to be very high, similar to or greater than RXTE (~2000 refereed publications.) In May 2016, MSFC's Advanced Concepts Office will perform a study of a US-led probe-class LOFT concept. This is presented on behalf of the LOFT consortium.

Author(s): Colleen A. Wilson-Hodge3, Paul S. Ray4, Deepto Chakrabarty[2], Marco Feroci[1]
Institution(s): *1. INAF-IAPS, 2. MIT, 3. NASA/MSFC, 4. NRL*

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303 – Mid-Career Prize Talk: In the Ring with Circinus X-1: A Three-Round Struggle to Reveal its Secrets, Sebastian Heinz (Univ. of Wisconsin)

303.01 – In the Ring with Circinus X-1: A Three-Round Struggle to Reveal its Secrets

I will discuss the science of X-ray light echoes from Galactic X-ray transients. When a bright transient flare is affected by a sufficiently high column of interstellar dust (N_H ~10^22 cm^-2), the scattered X-ray echo from the flare can take the form of well-defined rings. Resolved X-ray imaging of the rings allows us to construct sensitive probes of the dust mass distribution along the line of sight, to constrain dust properties like dust composition and grain size distributions, and to measure the distance to the X-ray source. With only three well-documented echoes reported to date, this is a relatively new field of study with a bright future. I will briefly touch on the requirements for future X-ray missions to advance the study of X-ray echoes.

Author(s): Sebastian Heinz[1]
Institution(s): *1. Univ. Of Wisconsin, Madison*

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304 – Science of X-ray Polarimetry in the 21st Century

304.01 – The Scientific Potential of X-ray Polarimetry

X-ray Polarimetry is a rich, untapped source of information on the geometry and/or magnetic structure of a wide range of cosmic object from accreting black holes to jets and neutron stars. This introductory overview will outline the basics of the production of polarized X-ray emission and emphasise its importance in our quest to understand how compact objects work.

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

304.02 – X-ray polarimetric studies of stellar mass black holes

Stellar mass black holes are among the brightest X-ray sources in the sky. Thus, they are excellent candidates for X-ray polarimetry, a technique that requires very large number of photons for a sensitive measurement. For accreting black holes in the thermal state, polarization provides important information about the black hole's spin magnitude and orientation relative to the observer. For black holes in the "low-hard" or "steep power-law" states, polarization provides a unique probe of the geometry of the hot electron corona.

Author(s): Jeremy Schnittman[1]
Institution(s): *1. NASA/GSFC*

304.03 – Scientific Drivers for X-Ray Polarimetry Observations of Active Galactic Nuclei and Blazars

Spectropolarimetric observations promise to give us insights into the structure of the the accretion flows and collimated outflows (jets) of mass accreting supermassive black holes. In this talk, I will present results from general relativistic ray tracing studies showing that the spectropolarimetric observations of bright Seyfert galaxies give information that is complimentary to that from Fe K-alpha line and Compton reflection hump spectroscopy. Combining polarimetric with spectral and timing results will allow us to pin down the physical properties of the accretion disk and corona with higher accuracy and with smaller systematic uncertainties. The X-ray polarimetric observations of blazars (mass accreting supermassive black holes with jets aligned with the line of sight) will allow us to study the structure of the magnetic field inside the jets (and thus to constrain the jet launching mechanism) in high synchrotron peaked blazars, and to identify and constrain the emission mechanism responsible for the X-ray to gamma-ray emission in low and intermediate synchrotron peaked blazars.

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

304.05 – Probes of Fundamental Physics using X-ray Polarimetry

The advent of X-ray polarimetry as an astronomical discipline is on the near horizon. Prospects of Explorer class missions currently under study in the NASA SMEX program, the Xipe mission under ESA study in Europe, and beyond to initiatives under development in Asia, indicate that the worldwide high energy astrophysics community view this as a high priority. The focal goal of X-ray polarization measurements is often to discern the geometry of a source, for example an accreting black hole, pulsing neutron star or a relativistic jet; these are addressed in other talks in this HEAD special session. In this talk, I discuss a parallel agenda, to employ X-ray polarimetry to glean insights into fundamental physics that is presently difficult or impossible to test in laboratory settings. Much of this is centered around neutron stars, and I will address theoretically-expected signatures of vacuum birefringence and photon splitting, predictions of QED theory in the strong magnetic fields possessed by pulsars and magnetars. Of particular note is that time-dependent polarimetry coupled with spectroscopy can help disentangle purely geometrical effects and fundamental physics ones. A brief discussion of possible tests of Lorentz invariance violation, expected in some theories of quantum gravity, will also be presented. Instrument requirements to realize such science goals will also be briefly covered.

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

304.06 – X-ray Polarization Probes of SNR and PWN

X-ray synchrotron radiation traces the high energy extrema of e+/e- accelerated by pulsar magnetospheres and supernova shocks. X-ray polarization lets us probe the unresolved geometry of these relativistic shock structures. I summarize what we know about magnetic field geometries in these nebulae and the prospects for learning more from X-ray polarimetry.

Author(s): Roger W. Romani[1]
Institution(s): *1. Stanford Univ.*

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305 – Making the Multimessenger – EM Connection

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306 – SNR/GRB/Gravitational Waves

306.01 – The 3D Distribution of 44-Ti in Cassiopeia A

The mechanisms behind core-collapse supernovae represent one of the most important unsolved problems in stellar astrophysics and are of interest to many branches of physics and astronomy, such as nucleosynthesis, pulsar formation, gamma-ray bursts, and gravitational wave production. Few direct observational constraints exist that probe fundamental parameters such as the explosion asymmetries and dynamics. One of the most direct probes of the physics of the core-collapse supernova engine is 44Ti, which is producing near the "mass cut" in the collapsing star with material interior to the 44Ti accreting onto the nascent compact object the the 44Ti mostly ejected during the explosion.

Here we present the results from the full *NuSTAR* observational campaign (over 2 Ms) of the famous Type II supernova remnant Cassiopeia A (Cas A). *NuSTAR* is the first X-ray observatory capable of focusing the X-rays that are emitted during the radioactive decay of 44Ti to 44Ca. For a supernova remnant like Cas A, which is both young and nearby, we can to image the distribution of the 44Ti ejecta. Early results (using the first 1 Ms of data) produced the first 2D maps of the 44Ti in Cas A, revealing the asymmetry in the 44Ti ejecta and the striking discrepancy between the distributions of 44Ti and the ionized Fe emission seen by *Chandra*. With the additional exposure time we can perform spatially-resolved spectroscopy to determine the Doppler shift of the 44Ti-emitting regions, giving us the ability to construct a 3D representation of the remnant. We can compare this to the excellent data from *Chandra* and *Spitzer* which have been used to perform similar studies of the ionized X-ray ejecta and IR emitting ejecta, respectively. We find an increasingly complex picture of the remnant, with 44Ti appearing wtih Fe in some regions on the remnant and other regions of Fe that are apparently 44Ti free. We will discuss our findings, and the implications of these results.

Author(s): Brian Grefenstette[1], Steven E. Boggs4, Chris Fryer[2], Fiona Harrison[1], Kristin Madsen[1], Hiromasa Miyasaka[1], Stephen P. Reynolds3, Andreas Zoglauer4
Institution(s): *1. Caltech, 2. Los Alamos National Laboratory, 3. NC State, 4. Space Sciences Laboratory*

306.02 – G346.6-0.2: A Rare Mixed-Morphology Supernova Remnant with Non-Thermal X-Ray Emission

The detection of non-thermal X-ray emission from supernova remnants (SNRs) provides us with a unique window into studying particle acceleration at the shock-front of an SNR. All of the 14 or so SNRs in which non-thermal X-ray synchrotron emission has been detected are shell-like in nature, and show no evidence of interaction with large nearby molecular clouds. Here we present a new X-ray study of the molecular cloud interacting mixed-morphology SNR G346.6-0.2 using XMM-Newton. We found that the X-ray emission arises from a cool recombining plasma with subsolar abundance, confirming previous Suzaku results. In addition, we identified an additional power-law component in the spectrum, with a photon index of ~2. We investigated its possible origin and conclude that this is most likely synchrotron emission produced by particles accelerated at the shock. We also derive the age of the remnant to be 1.8-2.3 kyrs assuming a distance of 8.3 kpc, which is much younger than previously suggested, while based on its morphology, Galactic location and the density of its environment as derived from our X-ray analysis, the progenitor of G346.6-0.2 was most likely a massive star.

Author(s): Katie Amanda Auchettl[2], B.T.T. Wong[3], Chi Yung Ng[3], Patrick O. Slane[1]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. The Ohio State University, 3. The University of Hong Kong*

306.03 – Galactic Astrophysics at TeV: One Year of Observations with HAWC

The High-Altitude Water Cherenkov Gamma Ray Observatory, or HAWC, is joint US/Mexican air shower array designed to observe gamma rays and cosmic rays between 100 GeV and 100 TeV. HAWC is currently the only high-uptime wide-field TeV observatory in operation. The observatory is carrying out an unbiased survey of the Northern Hemisphere, has a robust program to search for flares and other transient sources of gamma rays, and is well suited to observe spatially extended regions of gamma-ray emission and cosmic-ray anisotropy. HAWC recently concluded its first year of data taking with the complete array. The results include not only observations of many known TeV point sources, but also extended emission from Galactic objects like the Geminga supernova remnant. These results have implications for the origins of several astrophysical anomalies observed in the cosmic-ray data, such as the excess of Galactic positrons at Earth. We will describe results from HAWC with a focus on the observation of cosmic rays and Galactic sources of gamma rays.

Author(s): Segev BenZvi[1]
Institution(s): *1. University of Rochester*

306.04 – Eta Carinae's Hard X-ray Tail Measured with *XMM-Newton* and *NuSTAR*

Massive binary stellar systems drive shock plasma heating via the collision of winds from two stars (wind-wind collision: WWC). With typical (pre-shock) wind speeds of ≥1000 km s^{-1}, temperatures can reach as high as several tens of millions of Kelvin. X-ray emission from these stable shocks provides important tests of shock physics. While the spectrum below 10 keV is complicated by discrete line emission and absorption components, the X-ray spectrum above 10 keV is relatively simple. This high-energy emission therefore provides important clues on the condition of the maximum thermalized plasma where the winds collide head-on, while also providing important information about particle acceleration through the shock.

We obtained two coordinated X-ray observations of the super massive binary system η Carinae with *XMM-Newton* and *NuSTAR*, during the elevated X-ray flux state and just before the X-ray minimum flux state around the periastron passage in the summer of 2014. These *NuSTAR* observations clearly detected X-ray emission associated with η Car extending up to ~50 keV for the first time. The *NuSTAR* spectrum above 10 keV can be fit with the bremsstrahlung tail from a kT ~6 keV plasma, about 2 keV higher than those measured from the iron K emission line complex. This result may suggest that the companion star's pre-shock wind velocity is underestimated. The *NuSTAR* observation near the X-ray minimum state showed a gradual decline in the >5 keV emission by 40% in a day. The extreme absorption to the hardest emission component (N_H~1e24 cm^{-2}) suggests increased obscuration of the WWC X-ray emission by the thick primary stellar wind prior to superior conjunction. Neither observation detected the power-law component in the extremely hard band that *INTEGRAL* and *Suzaku* observed prior to 2011. If the non-detection by *NuSTAR* is caused by absorption, the power-law source must be small and located very near the WWC apex. Alternatively, it may be that the power-law source is not related to either η Car or the GeV gamma-ray source.

We also introduce the result of the latest *XMM-Newton* and *NuSTAR* joint observation of η Car performed in 2015 July.

Author(s): Kenji Hamaguchi[2], Michael F. Corcoran[2], Neetika Sharma[11], Theodore R. Gull[6], Hiromitsu Takahashi[5], Brian Grefenstette[1], Takayuki Yuasa[7], Martin Stuhlinger[3], Christopher Michael Post Russell[6], Anthony F. J. Moffat[9], Thomas Madura[2], Noel Richardson[12], Jose Groh[4], Julian Pittard[8], Stan Owocki[10]
Institution(s): *1. California Institute of Technology, 2. CRESST NASA's GSFC, 3. European Space Astronomy Centre, 4. Geneva University, 5. Hiroshima University, 6. NASA's GSFC, 7. RIKEN, 8. The University of Leeds, 9. Universite de Montreal, 10. University of Delaware, 11. University of Maryland, Baltimore County, 12. University of Toredo*

306.05 – Mergers of Binary Neutron Star Systems

We present results from fully relativistic simulations of binary neutron star mergers varying the tabular equation of state used to approximate the degenerate material and the mass ratio. The simulations incorporate both magnetic fields and the effects of neutrino cooling. In particular, we examine the amount and properties of material ejected from the merger. We gratefully acknowledge the support of NASA through the Astrophysics Theory Program grant NNX13AH01G.

Author(s): Patrick M. Motl[3], Matthew Anderson[2], Luis Lehner[5], Steven Liebling[4], David Neilsen[1], Carlos Palenzuela[6]
Institution(s): *1. Brigham Young University, 2. Indiana University, 3. Indiana University Kokomo, 4. Long Island University, 5. Perimeter Institute for Theoretical Physics, 6. Universitat de les Illes Ballears*

306.06 – Broadband Electromagnetic Follow-up of Advanced LIGO Sources

Advanced LIGO began observing in September 2015 with over 3 times the distance reach (27 times the sensitive volume) of its previous configuration. Some gravitational-wave sources, particularly neutron star binary mergers, are expected to produce broadband electromagnetic transients which may be crucial to understanding the astrophysical context of these events. We have assembled a consortium of over 60 ground- and space-based gamma-ray, x-ray, optical, infrared, and radio facilities collaborating to search for broadband electromagnetic counterparts of gravitational-wave sources. In this talk, we describe the LIGO/Virgo EM follow-up program and the astronomical facilities that participated during this first LIGO observing run. Then, we survey the multi-wavelength observing campaigns embarked upon for specific gravitational-wave events. Finally, we discuss lessons learned and the way forward for joint GW-EM observations in an era of increasingly sensitive GW detectors.

Submitted with The LIGO Scientific Collaboration and The Virgo Collaboration.

Author(s): Leo Pound Singer[1]
Institution(s): *1. NASA Goddard Space Flight Center*

306.07 – Estimating Long GRB Jet Opening Angles and Rest-Frame Energetics

We present a method to estimate the jet opening angles of long duration Gamma-Ray Bursts (GRBs) using the prompt gamma-ray energetics and a correlation between the time-integrated peak energy of the GRB prompt spectrum and the collimation-corrected energy in gamma rays. The derived jet opening angles using this method match well with the corresponding inferred jet opening angles obtained when a break in the afterglow is observed. Furthermore, using a model of the predicted long GRB redshift probability distribution observable by the Fermi Gamma-ray Burst Monitor (GBM), we estimate the probability distributions for the jet opening angle and rest-frame energetics for a large sample of GBM GRBs for which the redshifts have not been observed. Previous studies have only used a handful of GRBs to estimate these properties due to the paucity of observed afterglow jet breaks, spectroscopic redshifts, and comprehensive prompt gamma-ray observations, and we expand the number of GRBs that can be used in this analysis by more than an order of magnitude. In this analysis, we also present an inferred distribution of jet breaks which indicates that a large fraction of jet breaks are not observable with current instrumentation and observing strategies. We present simple parameterizations for the jet angle, energetics, and jet break distributions so that they may be used in future studies.

Author(s): Adam Goldstein[1], Valerie Connaughton[3], Michael Stephen Briggs[2], Eric Burns[2]
Institution(s): *1. NASA Postdoctoral Program, 2. Univ. of Alabama in Huntsville, 3. USRA*

306.08 – Strong constraints on gamma-ray burst emission in TeV using recent results from VERITAS

Recent VERITAS gamma-ray upper limits in the energy range 100 GeV to 30 TeV suggest that gamma-ray burst (GRB) emission in TeV is substantially suppressed compared to X-ray emission, and even compared to typically-observed Fermi-LAT emission in GeV. These results impact on our understanding of the GRB environment. We will present VERITAS results on GRB150323A and put them in context of what has been seen at lower energies by Swift and Fermi, both for this particular burst and for others.

Author(s): Ori Weiner[1]
Institution(s): *1. Columbia University*

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400 – AGN II

400.01 – Resolving the Cosmic X-ray Background with NuSTAR and Chandra

Although its origin was long mysterious, the cosmic X-ray background (CXB) is now known to be primarily the sum of emission from large number of active galactic nuclei (AGN). With the advent of NuSTAR, the first focusing high-energy X-ray observatory, we can now directly identify the sources that contribute to the bulk of the CXB at energies > 10 keV where the CXB spectrum peaks. I will present an analysis using data from the NuSTAR extragalactic survey program in which we using stacking techniques to determine the fraction of the CXB that is produced by X-ray sources identified at softer energies by deep Chandra observations. These results provide important constraints on AGN synthesis models fo the CXB and point toward a further "missing" population of obscured AGN. This work is supported in part by NASA award NNX15AP24G.

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

400.02 – Looking for early black holes signatures in the anisotropies of Cosmic backgrounds

We currently do not know how Super Massive Black Holes are seeded and grow to form the observed massive QSO at z~7. This is puzzling, because at that redshift the Universe was still too young to allow the growth of such massive black holes from stellar remnant black hole seeds. Theoretical models, taking into account the paucity of metals in the early Universe, explain this by invoking the formation of massive black holes seeds at z>10 as Direct Collapse Black holes of remnants of dead POPIII stars. As of today we cannot claim any detection of any high-z (z>7) black hole in their early stage of life. However, our recent measures of the arcminute scale joint fluctuations of the Cosmic X-ray Background and the Cosmic Infrared Background by Chandra and Spitzer can be explained by a population of highly absorbed z>10 Direct Collapse Black Holes.
I will review the recent discoveries obtained with different instruments and by different teams and critically discuss these findings and the interpretations.

Author(s): Nico Cappelluti[1]
Institution(s): *1. Yale University*

400.03 – Deeply X-raying the Local Universe

Swift/BAT and *INTEGRAL*/IBIS have revolutionized our view of Active Galactic Nuclei (AGN) in the local Universe. Their successful ongoing surveys count hundreds of AGN. However essential issues related to properties and evolution of AGN call for more sensitive surveys rather than larger numbers of AGN. To address these issues we have developed a new survey technique by merging the independent observations of BAT and IBIS/ISGRI: the *Swift-INTEGRAL* X-ray (SIX) survey. This survey capitalizes on the very uniform BAT sensitivity over the entire sky and the very deep sensitivity of IBIS/ISGRI over selected sky areas.
We present the SIX survey technique and its results in terms of properties and evolution of AGN in the local Universe. Finally we will show our predictions and simulations for an approved 9 Ms survey performed by *INTEGRAL*/IBIS on a selected sky area. This will allow us to build with the SIX a reference sample of AGN in the local Universe in terms of redshift – luminosity parameter space. We discuss this in the context of the *NuSTAR* survey.

Author(s): Eugenio Bottacini[1]
Institution(s): *1. Stanford University*

400.04 – Circumnuclear Star Formation in the BAT AGN Sample: High Resolution Radio Morphologies and SFRs

It has long been an assumption that active galaxies would obey the same far-infrared (FIR) - radio correlation established for star-forming normal galaxies. This assumption has been used by numerous high-z studies, but has recently come into doubt for two main reasons: the revelation that the AGN itself may contribute non-negligibly to the FIR emission, and different radio emission physics in the vicinity of the active nucleus than in isolated HII regions. Studies have attempted to decompose the FIR spectral energy distributions to remove the AGN contribution and then calculate the star formation rate (SFR). It would then be ideal to compare this to another, independent measure of SFR. We have conducted a high-resolution (0.3-1") JVLA survey of an unbiased sample of nearby, hard X-ray selected AGN in order to spatially decompose the extended star formation emission from the central compact source. We present these maps of the nuclear regions of 41 AGN from the Swift-BAT sample. The objects exhibit a wide range of circumnuclear radio morphologies, including mini-jets and star-forming rings. When the central compact source is removed, the extended emission does indeed conform to the FIR-radio correlation. A subset of the objects also remain compact in our 1" and 0.3" observations, implying very high star formation surface densities which may be capable of driving significant winds.

Author(s): Krista Lynne Smith[2], Richard Mushotzky[2], Stuart N. Vogel[2], Neal A. Miller[1]
Institution(s): *1. Stevenson University, 2. University of Maryland College Park*

400.05 – Testing the CMB Quenching for High-Redshift Radio Galaxies

The identification of a dozen of high-redshift (z > 4) blazars implies that a much larger population of powerful, but mis-aligned jetted AGNs already exists in the early Universe. However, this parent population remains elusive, although they are expected to be within the sensitivity threshold of modern wide-field radio surveys. One appealing mechanism is that the CMB photons upscatter the diffuse synchrotron radio emission in the lobes to the X-ray band. In this scenario, the lobes will turn into luminous X-ray sources. We analyzed the extended X-ray emission around several radio galaxies at z~4 and constructed their broad-band spectral energy distributions (SEDs). Modeling their SEDs will test this CMB quenching scenario for high-redshift radio galaxies.

Author(s): Jianfeng Wu[1], Elena Gallo[1]
Institution(s): *1. University of Michigan*

400.06 – Can Supermassive Black Holes Influence the Evolution of their Host Galaxies?

Powerful winds driven by active galactic nuclei (AGN) are often invoked to play a fundamental role in the evolution of both supermassive black holes (SMBHs) and their host galaxies, quenching star formation and explaining the tight SMBH-galaxy relations. A strong support of this "quasar-mode" feedback came from the recent X-ray observation of a mildly relativistic accretion disk wind in the ultraluminous infrared galaxy IRAS F11119+3257 hosting a luminous quasar at the center. Energetics arguments indicate a connection with a massive, large-scale molecular outflow observed in infrared with Herschel. This seems to be in agreement with theoretical models in which AGN winds drive hot bubbles in the host galaxy medium, thereby providing a link between the SMBH and the gas out of which stars form. This work was the "cover story" of the March 26th 2015 issue of Nature. Revolutionary improvements in this field are expected from ASTRO-H and Athena.

Author(s): Francesco Tombesi[2], Sylvain Veilleux3, James Reeves[1], Christopher S. Reynolds3
Institution(s): *1. Keele University , 2. NASA/GSFC, 3. University of Maryland*

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401 – The Unique Role of Very High Energy Observations in Multi-Wavelength Astronomy

401.01 – Very-High-Energy Astrophysics with the Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) will be a new gamma-ray observatory in the energy band ~30 GeV to ~100 TeV, designed to achieve an order of magnitude improvement in sensitivity over the currently operating imaging atmospheric Cherenkov telescopes. CTA will probe known sources with unprecedented sensitivity, angular resolution, and spectral coverage, with the potential of detecting hundreds of new sources. The CTA Consortium will also conduct a number of Key Science Projects, including a Galactic Plane survey and a survey of one quarter of the extragalactic sky. Data taken by CTA will be accessible by members of the wider astronomical community, for the first time in this energy band. This presentation will give an overview of CTA, and its proposed key science program.

Submitted with the CTA Consortium

Author(s): Reshmi Mukherjee[1]
Institution(s): *1. Barnard College, Columbia University*

401.02 – Spin-powered Pulsars in the CTA Era

What can CTA do for the study of isolated and binary neutron stars? Are the recent Crab observations the vanguard of numerous strong pulsed detections in the CTA era? Will the typical pulsar show only the tail of the Fermi spectrum? Or will we be tantalized by a handful of new unusual sources? I review our current HE picture and suggest that pulsar binaries represent a new TeV frontier.

Author(s): Roger W. Romani[1]
Institution(s): *1. Stanford Univ.*

401.03 – Connection of Very High Energy Gamma-ray Flares in Blazars to Activity at Lower Frequencies

The author will briefly review the results of multi-wavelength observations of blazars that emit very high-energy (VHE) gamma rays. The VHE gamma-ray emission is generally episodic, including flares that are often very short-lived. While many of these flares have counterparts only at X-ray energies, or no counterparts at all, some events are seen also at optical wavelengths, and a number are associated with the passage of new superluminal knots passing through the core in mm-wave VLBA images. Two explanations for the short-term VHE flares in the relativistic jets are supersonic turbulence and ultra-fast plasma jets resulting from magnetic reconnections. Observations of frequency-dependent linear polarization during flares can potentially decide between these models. VLBA images can help to locate VHE events that are seen at millimeter wavelengths. In some cases, the flares take place near the parsec-scale core, while in others they occur closer to the black hole.

This research is supported in part by NASA through Swift Guest Investigator grants NNX15AR45G and NNX15AR34G.

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

401.04 – Using the Long-term Optical/Infrared Color Variability to Trace the Gamma-ray Jet "State"

We have undertaken a 7-year, multiwavelength program to observe a sample of blazars in various Fermi gamma-ray states, using the Small and Medium Aperture Research Telescope System (SMARTS) 1.3m + ANDICAM instrument in Cerro Tololo, Chile. We present near-daily optical and infrared (OIR) color variability diagrams of these sources and compare the OIR flux and color to the Fermi gamma-ray flux on similar cadence. We then analyze the color variability properties on short and long timescales, as compared to the length of an average gamma-ray flare, to better constrain the physical mechanisms responsible for the variability properties that we observe. From this long-term observational data, we develop a schematic representation of the possible color variability behaviors in blazars and how it is related to the thermal disk and non-thermal jet contributions in both Flat Spectrum Radio Quasars and BL Lac objects.

Author(s): Jedidah Isler[1], C. Megan Urry[2], Charles D. Bailyn[2], Paolo S. Coppi[2], Imran Hasan[2], Emily MacPherson[2], Michelle Buxton[2]
Institution(s): *1. Vanderbilt University, 2. Yale University*

401.05 – Mapping supernova remnants and pulsar wind nebulae across decades of energy

Ground- and space-based gamma ray observatories of the past decade have given us a new understanding of particle accelerators in our galaxy. The improved spatial resolution and sensitivity of recent gamma-ray surveys of the Galactic plane have resolved confusion of sources identified numerous sources to study the physics of particle acceleration and the diffusion of energetic particles into the galaxy. Here I highlight some recent studies of Galactic accelerators from GeV to TeV energies, that allow us to disentangle hadronic from leptonic emission, constrain cosmic ray diffusion, and measure the conditions of particle acceleration. Supernova remnants and pulsar wind nebulae are found to be the two most common Galactic sources identified in very high energy gamma rays, and the future capabilities of CTA promise a dramatic increase in our knowledge of these classes which are currently limited to only a few of the most well-studied cases.

Author(s): John W. Hewitt[1]
Institution(s): *1. University of North Florida*

401.06 – Opportunities for Fundamental and New Physics with Very High Energy Gamma-ray Telescopes

Astronomical observations with the highest energy gamma rays enable a wide range of fundamental physics measurements as well as searches for new physics beyond the Standard Model. In this presentation, I will discuss indirect dark matter searches, intergalactic magnetic field constraints, and tests of Lorentz invariance with an emphasis on sensitivity gains that could be achieved with two new ground-based gamma-ray telescopes operating at the TeV energy scale: the High-Altitude Water Cherenkov observatory (HAWC) and the Cherenkov Telescope Array (CTA). Multiwavelength and multimessenger observations are an essential component of these studies needed to characterize the environments in which the highest energy gamma rays are produced, the conditions encountered while traversing interstellar and intergalactic distances, and "conventional" astrophysical backgrounds.

Author(s): Keith Bechtol[1]
Institution(s): *1. University of Wisconsin - Madison*

401.07 – The Impact of CTA on Future Space-Based High Energy Astrophysics Missions

The Cherenkov Telescope Array will provide a great leap forward in scientific capability for Very High Energy (VHE) gamma-ray astrophysics. In this talk I consider how the current observatory design and future science return from CTA might influence the science goals and design of future high energy astrophysics missions with a focus on the possibilities at gamma-ray energies.

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

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402 – Dark Matter, ISM, & Galaxies

402.01 – Recent Updates on the Searches for the 3.55 keV Line

The abundance of ubiquitous dark matter is now well quantified by observations, yet its nature remains unknown. Dark matter is believed to be composed primarily of an elementary particle. The search for this particle is one of the major efforts in astrophysics and particle physics today. X-ray observations of dark matter dominated objects have the potential to reveal a signal from decaying or annihilating dark matter. We previously reported the detection of an unidentified emission line at 3.55 keV in the stacked XMM-Newton observations of galaxy clusters. The origin of this unidentified line could be attributed to the decay of dark matter particles. I will present the new results from the stacked Suzaku observations of galaxy clusters and provide a comprehensive review on the detections and limits in the literature.

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

402.02 – A new deep, hard X-ray survey of M31: Identifying Black Holes and Neutron Stars in the X-ray Binary Population of our Nearest Neighbor

X-ray binaries (XRBs) trace old and new stellar populations in galaxies, and thus star formation history and star formation rate. X-ray emission from XRBs may be responsible for significant amounts of heating of the early Intergalactic Medium (IGM) at Cosmic Dawn and may also play a significant role in reionization. Until recently, the hard 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. The launch of NuSTAR, the first focusing hard X-ray observatory, has allowed us to resolve the brightest XRBs (down to LX ~ few times 10^38 erg/s) in galaxies like NGC 253, M83, and M82 up to 4 Mpc away. To reach much lower X-ray luminosities that are more typical of XRBs in the Milky Way (Lx <~ 10^37 erg/s), we have observed M31 in 4 NuSTAR fields for more than 1 Ms total exposure, covering younger stellar population in a swath of the disk (within the footprint of the Panchromatic Hubble Andromeda Treasury (PHAT) Survey) and the older populations of the bulge. We detect 120 sources in the 4-25 keV band and over 40 hard band (12-25 keV) accreting black holes and neutron stars, distinguished by their spectral shape in this band. The luminosity function (LF) of the hard band detected sources are compared to Swift/BAT-derived LFs of the Milky Way population, which reveals an excess of luminous sources in M31 when correcting for star formation rate and stellar mass. We also discuss implications for this updated understanding of XRB populations on early-Universe measurements in, e.g., the 7 Ms Chandra Deep Field survey.

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402.03 – A Local Perspective on HMXB Populations in the Early Universe

Deep studies of X-ray emission from galaxies, such as the *Chandra* Deep Field-South 4 Ms (soon to be 7Ms) survey, have allowed us to peer back in history at X-ray binary formation and evolution over cosmic timescales. X-ray stacking observations of z=1-4 star-forming galaxies reveal that the metallicity evolution of the Universe drives the evolution of the 2-10 keV X-ray luminosity per star formation rate (SFR), which is dominated by high mass X-ray binaries (HMXBs). By studying local (z=0.02-0.2), rare, analogs of these high redshift galaxies, we have found further evidence that the X-ray emission per SFR is elevated compared to typical local star-forming galaxies and this appears to be due to the lower metallicities of these galaxies. Theoretically, metal poor stars produce weaker stellar winds, which results in higher numbers of more massive binaries and therefore leads to higher X-ray luminosities in metal poor populations. We have performed an in-depth study of the only two local analogs that have spatially-resolved 2-10 keV emission with *Chandra* to present the bright end of the X-ray luminosity distribution of HMXBs. Based on this study, we conclude that the X-ray luminosity functions in these metal-poor galaxies differ from that of local star-forming galaxies. Since galaxies at high redshifts (and their binaries) formed in a more pristine universe, with few metals, the analogs that we have been studying offer cosmological insight about the heating of the early Universe by HMXBs.

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402.04 – The Circum-Galactic Medium of MASsive Spirals (CGM-MASS) I: Introduction to the XMM-Newton Large Project and a Case Study of NGC 5908

The Circum-Galactic Medium of MASsive Spirals (CGM-MASS) is a project studying the overall content, physical and chemical properties, and spatial distributions of the multi-phase circum-galactic medium (CGM) around a small sample of the most massive ($M_*>2\times10^{11}M_\odot$, $v_{rot}>300$km/s) isolated spiral galaxies in the local Universe. In this talk, we will briefly introduce the sample and the science goals and present the first detailed case study of the XMM-Newton observation of the hot gas halo of NGC5908. After careful data calibration, point source removal, and background analysis, we find the diffuse soft X-ray emission of NGC 5908 is significantly more extended than the stellar light in the vertical direction. The 0.5-1.25keV radial intensity profile tracing hot gas emission can be detected above the background out to ~2', or ~30kpc from the nucleus. The radial intensity distribution of hot gas can be characterized with a β-model with a core radius of r_{core}~8.8kpc and the β-index of β~0.8. The spectra extracted from the inner halo indicates an extremely low metallicity of $Z<0.1Z_\odot$ and a temperature of kT~0.5keV. The cooling radius is r_{cool}~27kpc or ~0.065r_{200}, within which the hot gas could cool radiatively within the cosmic time. Using the best-fit models of the spectra and the radial intensity profile, we further estimate some physical parameters of the hot gas and extrapolate them to larger radii. Adding the mass of cold atomic and molecular gases, hot gas, and stars, the total baryon fraction f_b within r_{200} is ~0.07, significantly below the cosmic baryon fraction of ~0.17. Therefore, ~60% of the baryons in the halo of NGC5908 is still “missing”. The hot gas accounts for ~56% of the total baryon content in the whole halo, but only ~2% within the cooling radius. By comparing NGC5908 to other galaxies or groups/clusters of galaxies, we find that it could be slightly X-ray brighter at a given stellar mass, when compared to lower-mass galaxies. NGC5908 also has f_b comparable to the typical value of a galaxy group with a similar halo mass or rotation velocity.

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402.05 – Dust Modeling of Si K Absorption in Galactic Bulge LMXBs with Chandra

The Galactic Bulge hosts a large number of bright and highly absorbed low-mass X-ray binaries (LMXBs). Column densities between 10^{22} cm^{-2} and 5×10^{23} cm^{-2} offer the opportunity and contrast to study the Si K edge structure with very high spectral resolution. Recent models predict that the total extinction in X-ray spectra not only involves X-ray absorption from gas and dust along the line of sight, but also significant contributions from dust scattering. A survey with the Chandra HETG of about a dozen LMXBs yields a rich variety of spectral features, showing that the Si K edge structure is highly complex and variable, from source to source and with time for a given source. We find substructure from neutral atomic silicon, silicate dust absorption and scattering from the interstellar medium (ISM), and superimposed ionized absorption signatures from the circumstellar environment of the LMXBs.

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402.06 – Detecting the Missing Metals and Missing Baryons Through X-Ray Spectroscopy

About 90% of the metals produced in the universe and 50% of the baryons are unaccounted for through UV-IR and radio studies of stars and gas. This large amount of missing gas and metals likely lies in a hot phase (0.5-10×10^6 K) and must be enriched to about 0.2-0.3 of the solar metallicity, so it should be a good absorber of X-rays in the resonance lines of common elements. Both existing data and simulations predict that hot galactic halos have N(H) ~1-10×10^{19} cm^{-2} and EW(OVII) = 3-10 mÅ, which are best studied with instruments that can resolve the lines, as the estimated line widths are 100-200 km/s. This sort of resolution and sensitivity is possible with grating spectroscopy of the type envisioned for missions such as *Arcus* and *X-Ray Surveyor*. These same instruments can probe the dynamics of the gas, and when applied to the halo of the Milky Way, can determine the rates of rotation and infall (or outflow) and the degree of turbulence.

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403 – Rapporteur Plenary Talk

Authors Index

Acosta Pulido, Jose: 106.25
Agnew, Ryan: 120.33
Akahori, Takuya: 111.03
Al Noori, Hind: **114.17**
Alford, Jason: **114.01**
Aliotta, Paul H.: 116.03
Allen, Glenn E.: **118.11**
Allen, Jessamyn: **120.01**
Allured, Ryan: **116.02**, 116.14
Alston, William: 106.19
Alvarez Crespo, Nuria: 106.20
Anderson, Craig: 110.04, 110.06
Anderson, Jay: 100.01, 106.17
Anderson, Matthew: 306.05
Anderson, Michael E.: 402.04
Andrade-Santos, Felipe: 101.02
Antoniou, Vallia: 110.02, **120.02**, 120.26, 120.33, 402.02
Archibald, Anne M.: 120.04
Archibald, Robert Frederic.: **114.02**
Arenberg, Jonathan: **116.12**
Arimoto, Makoto: 106.33
Arnaud, Keith A.: **115.02**
Arzoumanian, Zaven: 105.06, 114.06, **302.01**
Auchettl, Katie Amanda.: **306.02**
Avachat, Sayali S.: 100.02, **106.11**
Ayres, Thomas R.: **117.03**
Bachetti, Matteo: 120.14, 207.03
Baganoff, Frederick K.: 106.28, 110.02, 110.10
Bailey, Avery: **111.04**
Bailyn, Charles D.: 401.04
Ballantyne, David R.: **106.08**, **106.12**, **108.01**
Ballhausen, Ralf: 201.02
Balokovic, Mislav: **106.13**
Baring, Matthew G.: 105.04, **106.14**, 114.07, **304.05**
Barret, Didier: 120.07, 120.14
Barsotti, Lisa: **301.01**
Barthelmy, Scott Douglas.: 106.33, 120.20
Bartlett, Elizabeth: 120.12
Bassa, Cees: 120.04
Basu-Zych, Antara: 104.02, **402.03**
Bauer, Franz E.: 104.02, 118.06
Bautz, Mark W.: 101.02, 111.10, 402.01
Bayliss, Matthew: 101.02
Bazzano, Angela: 113.03
Beardmore, Andrew P.: 114.02, 116.11
Bechtol, Keith: **401.06**
Becker, Peter A.: 120.09, 120.24, 201.02, 201.08
Behar, Ehud: 109.03
Beheshtipour, Banafsheh: 202.04, **304.03**
Beiersdorfer, Peter: 115.01
Belmont, Renaud: 100.03
Belyaev, Mikhail: **114.04**, **119.01**
ben-Ami, Sagi: 116.14
BenZvi, Segev: **306.03**
Betancourt-Martinez, Gabriele: 115.01
Bhattacharyya, Sudip: 120.07
Binder, Breanna A.: 120.31
Bird, Tony: 120.12
Biretta, John A.: 100.01, 106.17
Black, Christine: 106.09
Blackburn, Lindy: 301.02
Blair, William P.: 118.08
Blanton, Elizabeth L.: 101.02
Bloser, Peter F.: 116.03, 116.04
Blundell, Katherine: 101.03
Bocchino, Fabrizio: 118.03
Bodaghee, Arash: **120.03**, **120.33**
Boettcher, Markus: 106.10, 106.14, 106.26, 106.32, 207.01
Bogdan, Akos: 111.08
Bogdanov, Slavko: 105.03, **105.05**, **120.04**
Boggs, Steven E.: 106.18, 120.03, 306.01
Borkowski, Kazimierz J.: **118.02**
Bostrom, Allison: **100.05**
Bottacini, Eugenio: **106.27**, **400.03**
Boyd, Patricia T.: 106.05, 110.02, 120.29, **120.30**, 120.32
Bozzo, Enrico: 113.03, 120.20
Brambilla, Gabriele: **114.05**, 114.11
Brandt, Soren: 113.03
Brandt, W. Niel.: 104.02, 106.18
Brazier, Adam: 105.03
Bregman, Joel N.: 110.05, 110.12, 111.06, 203.04, 402.04, **402.06**
Breiding, Peter: **106.15**
Breton, Rene: 114.17
Brickhouse, Nancy S.: 116.18
Briggs, Michael Stephen.: 301.02, 306.07
Brightman, Murray: **207.03**
Brooks, Alyson: 110.08
Brorby, Matthew: **120.05**
Brown, Alexander: 106.05
Brown, Gregory: 115.01
Brown, Shea: 111.04
Bruccoleri, Alexander Robert.: 116.10
Brumback, McKinley: **120.06**
Brunetti, Gianfranco: 101.04
Bucciantini, Niccolo: 118.01
Buckley, Matthew: 110.08
Buisson, Douglas: 100.03
Bulbul, Esra: **101.02**, **402.01**
Burderi, Luciano: 120.07
Burke, Douglas J.: 110.04, 110.06
Burns, Eric: **301.02**, 306.07
Burrows, David N.: 118.04, 118.05, 120.20
Buxton, Michelle: 109.05, 401.04
Cackett, Edward: 120.07, 120.14, **120.28**
Cadonati, Laura: **205.01**
Cafmeyer, Julian: 110.05
Camilo, Fernando: 105.03
Camp, Jordan: **103.05**, 301.02
Canizares, Claude R.: 402.05
Capellupo, Daniel M.: 106.28
Cappallo, Rigel: 120.31
Cappelluti, Nico: **400.02**
Caputo, Regina: **110.08**
Cara, Mihai: 100.02, 106.06, 106.11
Carnerero Martin, Maria Isabel.: 106.25
Casandjian, Jean-Marc: 110.14
Case, Gary L.: 118.09
Chakrabarty, Deepto: 120.01, 120.18, 302.06
Charles, Eric: 110.08
Chatterjee, Shami: 105.03
Chatzikos, Marios: 111.04
Chen, Chien-Ting J.: 106.18
Cherry, Michael L.: 118.09
Cheung, Chi C.: 120.08, 207.06
Chiaberge, Marco: 100.01, 106.17
Chiang, Chia-Ying: **120.07**
Chomiuk, Laura: 207.06
Christensen, Finn: 106.18, 120.03
Christensen, Nelson: 301.02
Christodoulou, Dimitris M.: 120.31
Churazov, Eugene: 101.01
Civano, Francesca M.: 106.18
Civitani, Marta M.: 116.02
Clark, Peter: 106.16
Clarke, Tracy E.: 101.03, 111.04
Clautice, Devon: 100.02, **106.06**
Coe, Malcolm J.: 120.12, 207.06
Coley, Joel Barry.: **120.08**, 207.06
collaboration, MAGNET: 201.07
Collaboration, NuSTAR: 109.08
Collmar, Werner: 112.04
Cominsky, Lynn R.: **113.04**
Connaughton, Valerie: 301.02, 306.07
Coppi, Paolo S.: **106.01**, 401.04
Corbel, Stephane: 109.04
Corbet, Robin: 120.08, 120.12, **207.06**
Corcoran, Michael F.: 306.04
Cordes, James M.: 105.03
Coriat, Mickael: 109.04
Corrales, Lia: **110.10**, 120.16, 120.22, 402.05
Cotroneo, Vincenzo: 116.02, 116.14
Courvoisier, Thierry J-L.: 113.03
Craig, William W.: 106.18, 120.03
Crain, Robert A.: 402.04
Crawford, Fronefield: 105.03
Cuadra, Jorge: 109.07
Cui, Xiaohong: 116.18
Cumbee, Renata: **117.05**
D'Abrusco, Raffaele: 106.20
D'Ai, Antonino: 120.07
Dahlin, Patrick: **110.12**
Dai, Lixin J.: 100.06
Dai, Xinyu: **111.06**
Dallilar, Yigit: 109.01
Dalton, Matthew: 118.12
Dauser, Thomas: 109.02, 201.03
de Geronimo, Gianluigi: 116.20
De Nolfo, Georgia: 302.04
Decourchelle, Anne: 118.03
Degenaar, Nathalie: 106.28
Deller, Adam T.: 120.04
Deneva, Julia S.: 105.03
Dhillon, Vik: 109.01
Di Stefano, Rosanne: **207.02**
Diltz, Chris Scott.: 106.26
DiPompeo, Michael A.: 106.09
Doty, John: 116.13
Drake, James: 101.05
Drake, Jeremy J.: 120.26
Drake, Stephen Alan.: **116.16**
Drlica-Wagner, Alex: 110.08
Dubus, Guillaume: 120.08, 207.06
Ducci, Lorenzo: 120.20
Dunham, Michael M.: 120.16
Dutan, Ioana: 106.22
Dwarkadas, Vikram: 118.04, **118.06**, **118.07**, **118.10**
Echt, Olof: 116.03
Edelson, Rick: 106.05
Edwards, Philip: 120.08, 207.06
Eggen, Joseph R.: 106.04
Egron, Elise: 120.07
Eikenberry, Stephen S.: **109.01**
Elvis, Martin: 106.02
Enoto, Teruaki: **114.06**
Eracleous, Michael: 402.02
Esposito, Paolo: 120.20
Eufrasio, Rafael T.: 104.02
Evans, Phil: 113.01, 120.20
Ezer, Cemile: 101.02
Fabbiano, Giuseppina: 106.02, 110.04, 110.06
Fabian, Andrew C.: 100.03, 101.03, 120.07, 120.14, **202.01**, **304.01**
Falcone, Abraham: 106.31
Falkner, Sebastian: 120.09, 201.03, **201.08**
Farnsworth, Damon: 111.04
Fender, Rob P.: 109.01, 109.04
Feng, Hua: 120.05
Ferdman, Robert: 105.03, 114.02
Feroci, Marco: 302.06
Ferrara, Elizabeth C.: **116.17**
Ferrigno, Carlo: 113.03, 201.03
Finger, Mark H.: 118.09
Forest, Cary: **300.02**
Forman, William R.: 101.01, 101.02, 111.07, 111.08
Fornasini, Francesca: 120.03
Foster, Adam: 116.11, **116.18**
Fragos, Tassos: **104.01**, 104.02, 402.03
Frank, Kari A.: **118.04**, **118.05**
Frechette, Eric: 120.33
Freire, Paulo: 105.03
Fruscione, Antonella: 110.04, 110.06
Fryer, Chris: **103.02**, 306.01
Fuerst, Felix: 120.24, 201.02, 201.06, **201.07**, 207.03
Fujita, Yutaka: 111.03
Fukumura, Keigo: **106.16**, 109.03
Gaensler, Bryan M.: 118.01
Galeazzi, Massimiliano: 117.04, **200.04**
Gallo, Elena: 400.05
Gandhi, Poshak: 109.01
Garcia, Javier: **109.02**, 110.10, 207.04
Garner, Alan: 109.01
Gaskins, Jennifer: 110.08
Gehrels, Neil: 106.05, 107.01, 114.02, 120.20

Gelfand, Joseph: 105.04, 114.07
Gelino, Dawn M.: 106.05
Gendreau, Keith C.: 302.01
Gendron-Marsolais, Marie-Lou: **101.03**, **111.08**
Georganopoulos, Markos: 100.01, 100.02, 106.06, 106.11, 106.15, **106.17**
Giglietto, Nicola: 107.02
Gilfanov, Marat: 104.02
Gill, Ramandeep: 105.04, **114.07**
Glikman, Eilat: 106.18
Gögüs, Ersin: 105.04
Gohil, Raj: 106.08
Goldstein, Adam: 301.02, **306.07**
Gomez, Jose: 106.22
Gonthier, Peter L.: **114.08**
Gorenstein, Paul: **103.06**
Goronostaev, Mikhail: 120.21
Gotthelf, Eric V.: 114.02, **114.09**, **117.01**
Gottlieb, Amy: **120.09**, 120.24, 201.02
Granot, Jonathan: 105.04, 114.07
Grant, Catherine E.: 111.10
Green, David: 118.02
Grefenstette, Brian: 207.03, **306.01**, 306.04
Grenier, Isabelle: 110.14
Griffin, Rhiannon: 111.06
Griffith, Christopher: **106.31**
Grinberg, Victoria: 109.02, 201.06, **207.04**
Groh, Jose: 306.04
Gu, Liyi: 111.03
Guainazzi, Matteo: 116.11
Guillot, Sebastien: 114.02
Gull, Theodore R.: 306.04
Guo, Jincheng: 207.02
Gupta, Anjali: 100.04, **203.01**
GW follow-up team, Swift: 113.01
Gwynne, Peter: 118.02
Haberl, Frank: 116.11, 120.12, 120.26
Haggard, Daryl: **106.28**
Hailey, Charles James.: 106.18, 120.03
Hainline, Kevin Nicholas.: 106.09
Halpern, Jules P.: 114.09, 120.04
Hamaguchi, Kenji: **306.04**
Hamann, Wolf-Rainer: 117.02
Hanlon, Lorraine: 113.03
Hanu, Andrei R.: 302.04
Hardee, Philip E.: 106.22
Harding, Alice Kust.: 105.04, 114.05, 114.07, 114.08, 114.11, 118.09, **207.01**
Harris, Daniel E.: 106.11
Harrison, Fiona: 106.13, 106.18, 114.02, 120.03, 120.14, 120.25, 207.03, 306.01, 402.02
Hartmann, Dieter: 106.22, **108.02**
Hasan, Imran: 401.04
Hays, Elizabeth A.: **116.21**, 118.09
Hegley, Jakob: 107.01
Heilmann, Ralf K.: **116.10**
Heinke, Craig O.: 106.28
Heinz, Sebastian: 111.09, **303.01**
Hell, Natalie: 115.01, 207.04
Hemphill, Paul Britton.: 120.09, 120.21, 120.24, 201.02, 201.03, **201.06**
Hendry, Doug: 106.16
Hertz, Edward: 116.02
Hessels, Jason: 105.03, 114.17, 120.04
Hewitt, John W.: **401.05**
Hickox, Ryan C.: 106.09, 106.18, **400.01**
Hirsch, Maria: 207.04
Hlavacek-Larrondo, Julie: 101.03, 111.08
Hodges-Kluck, Edmund J.: **110.05**, 110.12, **203.04**, 402.06
Hogan, Brandon Scott.: 106.06
Hogg, J. Drew: **120.10**
Hogge, Taylor: 111.04
Holder, Jamie: 106.30
Holland, Stephen: 112.02
Holley-Bockelmann, Kelly: **301.04**
Holmes, Danika: 118.07
Homan, Jeroen: 109.05, 120.01, 120.07
Hong, JaeSub: 120.26
Hoormann, Janie: **202.04**
Hornschemeier, Ann E.: 104.02, 110.02, 207.03, 402.02, 402.03
Hou, Meicun: **110.13**
Howell, Steve B.: 106.05
Hu, Chin-Ping: **114.10**
Huenemoerder, David: **117.02**, 207.04
Hunter, Stanley D.: 302.04, **302.05**
Huppenkothen, Daniela: **105.02**, 105.04, 114.07
Hwang, Una: 118.02
Iaria, Rosario: 120.07
Ignace, Richard: 117.02
Intema, Huib: 101.03
Isler, Jedidah: **401.04**
Iwanicki, Allana: 118.11
Jackson, Brenton: 120.33
Jackson, Tom: 116.14
Jahoda, Keith: 116.05
Jaodand, Amruta: 120.04
Jenke, Peter: 118.09
Ji, Li: 120.27
Johnson, Ryan: 101.02
Johnston, Simon: 118.12
Jones, Christine: 101.01, 101.02, 111.07, 111.08
Jones, Mackenzie L.: **106.09**
Jones, Thomas W.: 101.04
Jordan, Zachary: 120.33
Jorstad, Svetlana G.: 401.03
Jourdain, Elisabeth: **109.10**
Kaaret, Philip: 120.05, **203.05**
Kalapotharakos, Constantinos: **114.11**
Kalapotharakos, Constantions: 114.05
Kallman, Timothy R.: **116.05**
Kalogera, Vassiliki: 104.02
Kara, Erin: **100.06**, **202.03**
Karas, Vladimir: **106.29**
Kargaltsev, Oleg: 105.04, 114.07
Karovska, Margarita: 106.02
Kaspi, Victoria M.: 105.03, 114.02, 114.06
Kato, Yuichi: **111.03**
Kawai, Nobuyuki: 106.33
Kazanas, Demos: 106.06
Kazanas, Demosthenes: **109.03**, **112.01**, 114.05, 114.11
Keane, Evan: 114.02
Keek, Laurens: 106.12, **120.11**
Kelley, Richard L.: **206.02**
Kennea, Jamie: 110.02, **113.01**, 114.02, **120.12**, 120.20
Kim, Dong-Woo: **110.04**, 110.06
Kinch, Brooks: 202.06
King, Ashley L.: **102.01**
Kippen, R. Marc.: 116.03
Kislat, Fabian: 116.20
Klochkov, Dmitry: 120.21, 201.03, **201.04**, 201.06
Kochanek, Christopher S.: 111.06
Koh, Yew-Meng: 114.08
Komossa, St.: **103.03**
Kopacek, Ondrej: 106.29
Kosak, Katie: 106.11
Koss, Michael: 106.18
Koutroumpa, Dimitra: 110.14, 117.04, **200.02**
Kouveliotou, Chryssa: 105.04, 114.07, 116.05
Kovar, Jiri: 106.29
Kraft, Ralph P.: **101.01**, 111.08
Krawczynski, Henric: **116.20**, 202.04
Kretschmar, Peter: 201.03, 201.06
Krimm, Hans A.: 106.33, 120.20
Krivonos, Roman: 120.03
Krizmanic, John F.: 302.04
Krolik, Julian H.: 202.06
Krumrey, Michael: 116.13
Krzanowski, James E.: 116.03
Kühnel, Matthias: 120.09, 120.18, 120.21
Kunneriath, Devaky: 106.29
Kuntz, K. D.: 117.04, 118.08, 200.03, **200.06**
KUNTZ, Kip: 110.14
Kuulkers, Erik: 113.03
Lallement, Rosine: **110.14**
LaMarr, Beverly: 116.13
LaMassa, Stephanie M.: **106.18**
Lamb, Frederick K.: **120.13**
Landoni, Marco: 106.20
Lansbury, George: 106.18
Laubis, Christian: 116.13
Lauer, Jennifer L.: 110.04, 110.06
Laurent, Philippe: 113.03
Laycock, Silas: 120.12, 120.31
Lazarus, Patrick: 105.03
Lebrun, François: 113.03
Legere, Jason S.: 116.03, 116.04
Lehmer, Bret: **104.02**, 110.02, 402.02, 402.03
Lehner, Luis: 306.05
Leutenegger, Maurice A.: 115.01, 207.04
Li, Hui: 106.10
Li, Jiang-Tao: **118.03**, **402.04**
Li, kunyang: 106.11
Li, Xiang-Dong: 120.27
Li, Zhiyuan: 110.13
Liebling, Steven: 306.05
Lin, Dacheng: 120.07
Lin, Lin: 105.04
Lister, Matthew L.: 106.06
Littenberg, Tyson: 301.02
Littlefair, Stuart: 109.01
Liu, Jifeng: 207.02
Liu, Siming: 120.27
Liu, Wenhao: 117.04, **200.05**
Lohfink, Anne: **100.03**, **106.19**
Long, Knox S.: **118.08**
Ludlam, Renee: **120.14**
Luo, Bin: 104.02
Lynch, Ryan: 105.03
Lyons, David: 117.05
Ma, Y. K.: 118.01
Maccarone, Thomas J.: 110.02, 120.31, 402.02
Machacek, Marie E.: 101.01
MacPherson, Emily: 401.04
Madsen, Erik: 105.03
Madsen, Kristin: 306.01
Madura, Thomas: 306.04
Mahmoodifar, Simin: **120.15**, 120.23
Majid, Walid A.: **114.16**
Makishima, Kazuo: 111.03
Maksym, W. Peter.: 106.02
Malonis, Andrew: 116.13
Malzac, Julien: 100.03
Marcu, Diana: 120.09
Marcu-Cheatham, Diana: 120.24
Marcu-Cheatham, Diana Monica.: **201.02**
Margutti, Raffaella: **103.01**
Markevitch, Maxim L.: **101.04**
Markoff, Sera: 106.28
Markowitz, Alex: 120.21
Marquez, Vanessa: 116.02
Marscher, Alan P.: **401.03**
Marsh, Thomas: 109.01
Marshall, Herman L.: 106.06
Martin, Pierrick: 110.08, 207.06
Masetti, Nicola: 106.20
Massaro, Francesco: **106.20**
Mathur, Smita: **100.04**
Maune, Jeremy: 106.04
McBride, Vanessa: 120.08, 120.12, 207.06
McClintock, Jeffrey E.: 109.02
McCollough, Michael L.: 110.04, 110.06, **120.16**
McConnell, Mark L.: **112.04**, 116.03, 116.04
McDonald, Michael: 111.10
McEnery, Julie E.: **401.07**
McEntaffer, Randall L.: **116.19**
McLaughlin, Maura: 105.03, 114.17
McLin, Kevin M.: 113.04
Meli, Athina: 106.22
Mereghetti, Sandro: 113.03
Mesinger, Andrei: **104.04**
Meyer, Eileen: 100.02, 106.15, 106.17
Meyer, Eileen T.: **100.01**
Miceli, Marco: 118.03
Mihara, Tatehiro: 106.33
Miles, Drew M.: **116.22**
Milisavljevic, Dan: 106.20
Miller, Eric: 101.02, 116.11
Miller, Eric D.: **111.10**, 402.01
Miller, Hugh R.: **106.04**
Miller, Jon M.: 100.05, 100.06, 120.07, 120.14, 120.25, **300.03**

Miller, M. Coleman.: 120.07, 120.13, **120.17**
Miller, Matthew J.: 203.04, 402.06
Miller, Neal A.: 400.04
Mineo, Stefano: 104.02
Mirabel, I. Felix.: 120.05
Mitsuda, Kazuhisa: 206.02
Miyasaka, Hiromasa: 306.01
Mizuno, Yosuke: 106.22
Moffat, Anthony F J.: 306.04
Moiseev, Alexander: **116.08**
Mooley, Kunal: 109.01
Moran, Edward C.: **106.07**
Morgan, Douglas: 110.04, 110.06
Mori, Kaya: 120.03
Morsony, Brian J.: **111.09**
Moskalenko, Igor V.: 107.02
Mossman, Amy: 110.04, 110.06
Motl, Patrick M.: **306.05**
Motta, Sara: 109.04
Mueller, Guido: **301.05**
Mukai, Koji: **206.03**
Mukherjee, Reshmi: **401.01**
Mullen, Patrick: 117.05
Murray, Stephen S.: 101.02
Mushotzky, Richard: 106.05, 400.04
M\'endez, Mariano: 120.27
Nakahira, Satoshi: 106.33
Nakazawa, Kazuhiro: 111.03
Natalucci, Lorenzo: 113.03, 120.14
Neilsen, David: 306.05
Neilsen, Joseph: 106.28, **109.04**, **109.05**
neilson, hilding: 117.02
Ng, Chi Yung: **118.01**, 306.02
Ng, Chi-Yung: 114.10
Niemiec, Jacek: 106.22
Nishikawa, Ken-Ichi: **106.22**
Noble, Scott: 202.06
Nordlund, Aake: 106.22
Norman, Colin Arthur.: 100.01, 106.17
Nowak, Michael: 106.28, **120.18**, 207.04
Nugent, Jenna: 111.06
Nulsen, Paul: 101.01, 111.07, 111.08
O'Brien, P. T.: **112.03**, **116.01**
O'Sullivan, Ewan: 110.04, 110.06
Oda, Ryoma: 106.33
Oh, Siang P.: 101.04
Okajima, Takashi: 107.01, 116.20
Orlando, Elena: **107.02**, **107.04**
Oskinova, Lidia: 117.02
Owen, Frazer N.: 106.11
Owocki, Stan: 306.04
Oya, Igor: 118.12
Page, Kim L.: 110.02
Paggi, Alessandro: **106.02**, 106.20, 110.04, **110.06**
Palenzuela, Carlos: 306.05
Pannuti, Thomas: 118.11
Pareschi, Giovanni: 116.02
Parker, Michael: 120.07, 120.14
Patel, Chitrang: 105.03
Paterno-Mahler, Rachel: 101.02
Pavlov, George G.: 105.04
Pe'er, Asaf: 106.22
Peacock, Mark: **120.19**
Peris, Charith: **109.06**
Perlman, Eric S.: 100.01, **100.02**, 106.06, 106.11, 106.17, 106.30
Peruta, Carolyn: 113.04
Petre, Robert: 118.02, 206.03
Phillipson, Rebecca: 120.30, **120.32**
Pinto, Ciro: 106.19
Pittard, Julian: 306.04
Pivovaroff, Michael: 114.02
Plucinsky, Paul P.: 116.11, 402.02
Pohl, Martin: 106.22
Pollock, Andrew: 116.11
Ponti, Gabriele: 106.28, 109.04
Pooley, David A.: 402.02
Pooley, Guy G.: 109.06
Porter, Frederick S.: 115.01
Postnov, Konstantin: 120.21
Pottschmidt, Katja: 110.02, 120.09, 120.21, 120.24, 201.02, 201.03, 201.06, 207.04
PRAXyS Team, The: 116.05
Prestwich, Andrea H.: 120.05
Prigozhin, Gregory: **116.13**
Primini, Francis A.: 207.02
Proga, Daniel: **300.01**
Ptak, Andrew: 110.02, 207.03, 402.02, 402.03
Racusin, Judith L.: 112.01, 301.02
Rafikov, Roman R.: 119.01
Rahoui, Farid: 109.05, 120.03
Raino', Silvia: 107.02
Raiteri, Claudia Maria.: 106.25
Rana, Vikram: 120.14
Ranalli, Piero: 104.02
Randall, Scott W.: 101.01, 101.02, **111.07**, 111.08
Ransom, Scott M.: 105.03
Rappaport, Saul A.: 111.10
Ray, Paul S.: **105.06**, 302.06
Reddy, Ratuja: 118.06
Reeves, James: 400.06
Reid, Paul B.: 116.02, 116.14
Remillard, Ronald A.: 109.02, 109.06, 116.13, 207.05, **302.02**
Reynolds, Christopher S.: 100.06, 101.05, 106.19, 111.09, 115.01, 120.10, 400.06
Reynolds, Stephen P.: 118.02, 306.01
Ricarte, Angelo: 106.18
Ricci, Claudio: 106.18
Ricci, Federica: 106.20
Richardson, Noel: 306.04
Rivers, Elizabeth: **106.23**
Roberg-Clark, Gareth: **101.05**
Roberts, Mallory: 114.17
Roberts, Oliver: 105.04
Rodriguez, Jerome: 109.06
Roediger, Elke: 101.01, 111.08
Romani, Roger W.: **114.14**, **304.06**, **401.02**
Romano, Patrizia: 106.25, **120.20**
Romero-Canizales, Cristina: 118.06
Roming, Peter: **112.02**
Roques, Jean-Pierre: 109.10, 113.03
Rothschild, Richard E.: **120.21**, 201.06
Roustazadeh, Parisa: **106.32**
Rudnick, Lawrence: 111.04
Russell, Christopher Michael Post.: **109.07**, 306.04
Ruszkowski, Mateusz: **110.03**
Ryan, James M.: 116.04
Ryu, Dongsu: 101.04
Sadowski, Aleksander: **202.05**
Saitoh, Shinya: 106.01
Sakamoto, Takanori: **106.33**, 107.01
Salmaso, Bianca: 116.02
Salvo, Tiziana: 120.07
Santander, Marcos: **107.03**
Sapkota, Dhaka Mohan.: **116.06**
Sarazin, Craig L.: 101.02, 111.04
Savchenko, Volodymyr: **113.03**
Schattenburg, Mark: 116.10
Schlitz, Joseph: 107.01
Schneider, Donald P.: 104.02
Schnittman, Jeremy: **202.06**, **304.02**
Scholz, Paul: **105.03**
Scholze, Frank: 116.13
Schultz, David R.: 117.05
Schulz, Norbert S.: 117.02, 120.01, 207.04, **402.05**
Schwanke, Ullrich: 118.12
Schwarm, Fritz-Walter: 120.24, 201.02, 201.03, 201.08
Schwartz, Daniel A.: 116.14
Sembay, Steve: 116.11
Serino, Motoko: 106.33
Seymour, Andrew: 105.03
Sharma, Neetika: 306.04
Shawhan, Peter S.: 301.02
Shelton, Robin L.: 117.05, **203.03**
Shemmer, Ohad: 104.02
Shenar, Tomer: 117.02
Shirazi, Farzane: **116.03**
Shrader, Chris R.: **106.03**, 109.03
Simionescu, Aurora: 111.03
Simonnet, Aurore: 113.04
Singer, Leo Pound.: 301.02, **306.06**
Slane, Patrick O.: 118.01, 306.02
Slany, Petr: 106.29
Smale, Alan P.: 116.16, 120.29, 120.30, 120.32
Smith, Evan: **106.30**
Smith, Howard Alan.: 106.20
Smith, Krista Lynne.: **106.05**, **400.04**
Smith, Randall K.: 101.02, 110.09, 116.18, **120.22**, **302.03**
Snowden, Steve L.: **200.03**
Snowden, Steven L.: 110.14
Sohn, S. Tony: 100.01, 106.17
Sol, Helene: 106.22
Sparks, William B.: 100.01, 106.11, 106.17
Spitler, Laura: 105.03
Sschoenherr, Gabriele: **201.03**
Stairs, Ingrid H.: 105.03
Stancil, Phillip C.: 117.05
Stappers, Benjamin: 105.03
Staubert, Rüdiger: 120.21, **201.05**, 201.06
Stawarz, Lukasz: 106.01
Stecker, Floyd W.: 302.04
Steiner, James F.: 109.02, 109.06, 120.31, **207.05**
Stelter, R. Deno: 109.01
Stern, Daniel: 106.18, **106.24**, 114.02, 120.03, 402.02
Stevens, Abigail L.: **105.01**
Stevens, Jamie: 120.08, 207.06
Stone, James Mclellan.: 119.01
Storchi-Bergmann, Thaisa: 106.02
Strader, Jay: 207.06
Strohmayer, Tod E.: 120.15, **120.23**
Strong, Andrew: 107.02
Stuchlik, David: 116.20
Stuhlinger, Martin: 116.11, 306.04
Su, Yuanyuan: 101.01
Suchy, Slawomir: 120.09
Summerlin, Errol J.: 106.14
Sundqvists, Jon O.: 207.04
Sushch, Iurii: **118.12**
Swisdak, M.: 101.05
Takada, Atsushi: **116.09**
Takahashi, Hiromitsu: 306.04
Takahashi, Masaaki: 106.16
Takahashi, Tadayuki: **206.01**
Takizawa, Motokazu: 111.03
Tan, William: 118.11
Tananbaum, Harvey: 116.14
Tanimori, Toru: 116.09
Taylor, Gregory B.: 101.03
Temim, Tea: 118.01
Tendulkar, Shriharsh P.: 114.02, 207.03
The SMC XVP Collaboration, &: 120.26
Thorpe, James: **301.03**
Thrush, Samantha: 106.32
Timokhin, Andrey: 114.05, 302.04
Tobler, Jennifer: 112.02
Tombesi, Francesco: 106.06, 106.16, 109.03, **400.06**
Tomsick, John: 114.02, 120.03, 120.14, 120.33, **202.02**
Torpin, Trevor: **120.29**
Townsend, Lee: 120.12, 207.06
Townsend, Richard D.: 207.04
Tozzi, Paolo: 104.02
Treister, Ezequiel: 106.18
Trier Frederiksen, Jacob Trier.: 106.22
Trinchieri, Ginevra: 110.04, 110.06
Trolier-McKinstry, Susan: 116.02, 116.14
Trump, Jonathan R.: 104.02
Tsavalas, John G.: 116.03
Ubertini, Pietro: 113.03
Urry, C. Megan.: 106.18, 401.04
Ursino, Eugenio: **117.04**
Uttley, Phil: 105.01
Valencic, Lynne A.: **110.09**, 120.22, 120.29
van der Horst, Alexander: 105.04
van der Klis, Michiel: 105.01
Van Der Marel, Roeland P.: 100.01, 106.17
van Leeuwen, Joeri: 105.03
Van Weeren, Reinout J.: 111.04
Varniere, Peggy: 109.06
Vasilopoulos, Georgios: 120.12
Veilleux, Sylvain: 111.10, 400.06
Veitch, John: 301.02
Venter, Christo: 207.01

Venters, Tonia M.: **302.04**, 402.02
Vercellone, Stefano: **106.25**, 120.20
Vignali, Cristian: 104.02
Vikhlinin, Alexey: 116.02, 116.14
Villata, Massimo: 106.25
Vink, Jacco: 118.03
Vogel, Stuart N.: 400.04
Vrtilek, Saeqa Dil.: 109.06
Vydra, Ekaterina: 107.01
Wadiasingh, Zorawar: 207.01
Wallace, Margeaux L.: 116.02, 116.14
Walton, Dom: **109.08**, 207.03
Wang, Daniel: 109.07, **109.09**, **203.02**, 402.04
Wang, Junfeng: 106.02
Wang, JunXian: 104.02
Wang, Na: 120.27
Wasti, Sambid K.: **116.04**
Watanabe, Ken: **107.01**
Watts, Anna: 105.04
Weidenspointner, Georg: 113.03
Weiner, Ori: **306.08**
Wiggins, Brandon: **110.11**
Wik, Daniel R.: 110.02, 111.04, **402.02**
Willett, Rebecca: 118.02
Williams, Benjamin F.: 402.02
Wilms, Joern: 110.10, 120.09, 120.18, 120.21, 120.24, 201.02, 201.03, 201.06, 201.08, 207.04
Wilson, Lynn: 101.04
Wilson-Hodge, Colleen A.: **118.09**, **302.06**
Winkler, P. Frank.: 118.08
Wolff, Michael Thomas.: 120.09, **120.24**, **201.01**, 201.02, 201.08
Wong, B.T.T.: 306.02
Wong, Emily N.: 116.03
Wood, Kent: 120.24
Wood, Kent S.: 120.09, 201.02
Wood, Matthew: 110.08
Wright, Nick: 120.26
Wu, Jianfeng: **400.05**
Xue, Yongquan: 104.02
Yan, Shu-Ping: **120.27**
Yang, Hsiang-Yi Karen: 110.03
Yang, Jun: 120.31
Yaqoob, Tahir: 106.18
Yoshida, Atsumasa: 106.33
Younes, George A.: **105.04**, 114.07
Yuan, Qiang: 109.09
Yuasa, Takayuki: 306.04
Yukita, Mihoko: 104.02, **110.02**, 207.03, 402.02, 402.03
Yusef-Zadeh, Farhad: 106.28
Zepf, Steve E.: 120.19
Zezas, Andreas: 104.02, 110.02, 120.02, **120.26**, 120.33, 207.03, 402.02, 402.03
Zhang, Binbin: 301.02
Zhang, Haocheng: **106.10**, **106.26**
Zhang, William: 106.18, 120.03
Zhang, Xiao-Ling: 118.09
Zhu, Weiwei: 105.03
Zoghbi, Abderahmen: **120.25**
Zoglauer, Andreas: 306.01
Zweibel, Ellen Gould.: 110.03