

13th HEAD Meeting – Monterey, CA April, 2013

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101 – AGN I: Winds/jets/accretion (obs) and Variability

101.01 – Microlensing Constraints on Quasar X-ray Emission Regions

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Gravitational microlensing provides a unique probe of the innermost parts of quasar accretion disks, close to the event horizon of supermassive black holes. We report our long-term monitoring results, including our recent large Chandra program for seven gravitationally lensed quasars: Q2237+0305, RXJ1131-1231, QJ0158-4325, SDSS0924+0219, SDSS1004+4112, HE0435-1223, and HE1104-1805. We discover for the first time chromatic microlensing differences between the soft and hard X-ray bands in the X-ray continuum emission. Our results indicate that the coronae above the accretion disk thought to generate X-rays have a non-uniform electron distribution, and the hard X-ray emission region is smaller than the soft region in two cases tracking the event horizon of black holes. We detect metal emission lines for almost all X-ray images in all lenses. We measure larger equivalent line widths in lensed quasars compared to a large sample of normal non-lensed AGNs of similar luminosities. We conclude that the iron line emission region is smaller than that of the X-ray continuum, possibly resulting from strong gravitational lensing near the black hole. Our results also confirm earlier microlensing results that quasar X-ray emission regions are significantly smaller than the optical emission regions. We also discuss the prospects of our on-going large Chandra Cycle 14/15 monitor program.

101.02 – X-ray Reverberation Lags in 1H0707-495 and IRAS 13224-3809

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The discovery of X-ray reverberation lags in Active Galactic Nuclei has opened a new perspective through which to study the innermost regions of supermassive black holes. Reverberation lags measure the light travel time between direct X-ray continuum emission produced in the corona, and the reflected emission off the nearby accretion disc, allowing us to probe distances of tens of lightseconds in galaxies that are hundreds of millions of lightyears away. In this talk, I will present the timing analysis of two famous Narrow-Line Seyfert 1 galaxies, 1H0707-495 and IRAS 13224-3809. For 1H0707-495, we have compiled 1.3 Ms of archival XMM-Newton data, in order to take the closest ever look at the structure of the reverberation lag in this source, and have discovered a lag in the relativistically broadened Fe K line emission, relative to the continuum. For IRAS 13224-3809, we use a 500 ks observation to examine the flux dependence of reverberation lags, and find that when the source is in quiescence, the amplitude of the lag is smaller and occurs on faster timescales than when the source flares. This result suggests that a change in flux corresponds to a change in the physical size and location of the continuum-emitting corona. Reverberation lags are beginning to help answer some big questions in X-ray astronomy, by probing the innermost regions of AGN in a new way.

101.03 – X-ray Reverberation Mapping in AGN

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Active galaxies often show inter-band X-ray time lags. Recently, the first signatures of reverberation were seen between the direct and the reflected emission dominating the soft excess in some AGN. The delays are comparable to the light-crossing time a few gravitational radii from the central supermassive black hole. Reverberation in the iron K band, a better understood part of the spectrum, were later detected where the peak of the line is delayed with respect to its wings. Such results, which are presented and discussed here, not just confirmed the interpretation of these lags as being due to reverberation in the vicinity of the black hole, but also are allowing us to use this clean part of the spectrum to better probe and constrain the emission region at these extreme environments.

101.04 – Fermi LAT Observations of Gamma-ray Flaring in the Gravitationally Lensed Blazar B0218+357

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Contributing teams: Fermi-LAT Collaboration

Beginning mid-2012, increased gamma-ray activity from the radio double-imaged gravitationally lensed blazar B0218+357 was observed with the Fermi Large Area Telescope (LAT). The sustained flaring with daily fluxes greater than 10x the source's nominal level afforded an opportunity to uniquely measure the expected gravitational lens delay in gamma rays. Additionally, Fermi-LAT pointed observations of the anticipated delayed emission from the brightest flares with peaks ~60x its nominal flux at the end of September 2012 allowed us to constrain the magnification ratio between the images in gamma-rays. We will present the results from our timing and spectral analysis of B0218+357 and consider prospects for future LAT studies of gravitationally lensed systems.

101.05 – Emergence of an Outflow in the Seyfert Galaxy Mrk 335 Revealed by XMM-Newton and HST

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I will present the discovery of an outflowing ionized wind in the Seyfert 1 Galaxy Mrk 335 observed by XMM-Newton and HST/COS. This bright source was not known to host warm absorber gas until recent XMM-Newton observations in combination with a long-term Swift monitoring program have shown extreme flux and spectral variability. Our findings are based on high resolution spectra obtained by the RGS detector reveal that the wind consists of three distinct ionization components outflowing at a velocity of ~5000 km/s. The analysis of multi-epoch RGS spectra allowed us to compare the absorber properties at three very

different flux states of the source and conclude that the appearance of the absorber is not correlated with the X-ray flux. We have searched for absorption signature in archival and non-simultaneous UV data from HST (FOS, STIS, COS) in this source that so far was known for being absorption-free in the UV band. In the COS spectra obtained a few months after the X-ray observations we found broad absorption in CIV lines intrinsic to the AGN and blueshifted by a velocity roughly comparable to the X-ray outflow. The global behavior of the gas in both bands can be explained by variation of the covering factor and/or column density, possibly due to transverse motion of absorbing clouds moving out of the line of sight at Broad Line Region scale. This is one of the very few AGNs where a variable covering factor of the absorbing gas could be observed in high resolution spectra.

101.06 – Unification of X-ray Winds in Seyfert Galaxies: From Ultra-fast Outflows to Warm Absorbers

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The existence of ionized X-ray absorbing layers of gas along the line of sight to the nuclei of Seyfert galaxies is a well established observational fact. This material is systematically outflowing and shows a large range in parameters. However, its actual nature and dynamics are still not clear. In order to gain insights into these important issues we performed a literature search for papers reporting the parameters of the soft X-ray warm absorbers (WAs) in 35 type 1 Seyferts and compared their properties to those of the ultra-fast outflows (UFOs) detected in the same sample. The fraction of sources with WAs is >60%, consistent with previous studies. The fraction of sources with UFOs is >34%, >67% of which also show WAs. The large dynamic range obtained when considering all the absorbers together allows us, for the first time, to investigate general relations among them. In particular, we find significant correlations indicating that the closer the absorber is to the central black hole, the higher the ionization, column, outflow velocity and consequently the mechanical power. The absorbers continuously populate the whole parameter space, with the WAs and the UFOs lying always at the two ends of the distribution. This strongly suggest that these absorbers, often considered of different types, could actually represent parts of a single large-scale stratified outflow observed at different locations from the black hole. The observed parameters and correlations are consistent with both radiation pressure through Compton scattering and MHD processes contributing to the outflow acceleration, the latter playing a major role. Most of the absorbers, especially the UFOs, have a sufficiently high mechanical power to significantly contribute to the AGN feedback.

101.07 – Zooming in on the Central Regions of a Radio-loud AGN -- 3C120

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We present a detailed study of the central engine structure in the broad-line radio galaxy 3C120 using a multi-epoch analysis of a deep XMM-Newton observation (taken in 2003) and two deep Suzaku pointings (in 2012), providing the closest look at 3C120 to date. In order to place our X-ray spectral data into the context of the known disk-disruption/jet-ejection cycles displayed by this object, we consider monitoring of the source in the UV/X-ray bands by RXTE and Swift using the UV flux as a proxy for the accretion disk emission and the X-ray flux for the coronal emission. We find two acceptable descriptions of the X-ray data. Using a spectral model in which the soft X-ray excess in 3C120 is described by reflection from an ionized accretion disk, we conclude that the accretion disk must truncate at times of low/rising X-ray flux, in agreement with the jet-cycle picture. Alternatively, no accretion disk reflection changes are required if, instead, the soft excess is described by a second power-law component that may be identified as originating from the jet. We also study short-timescale variability, finding two characteristics, a positive X-ray flux/hardness correlation and the lack of a UV/soft-excess correlation, that are markedly different from those found in Seyfert galaxies. This may be taken as further evidence that the jet is contributing to the soft X-ray band. We also show how the two scenarios could be distinguished using Nustar or Astro-H.

101.08 – Proper Motion and Relativistic Velocities in the Optical Synchrotron Jet of M87

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Using over 13 years of archival HST observations of the relativistic jet in the archetypal radio galaxy M87, we have produced astrometric speed measurements of the optically bright synchrotron-emitting plasma components in the jet with unprecedented accuracy. Building on previous work showing the superluminal nature of the jet in the optical, we have found that the jet motion is incredibly complex, with both transverse motions and flux variations which can be seen by the naked eye in the time-series of deep exposures. These observations of M87 provide us with a unique dataset with which to refine theoretical models of the large-scale jet structure, potentially addressing open questions such as the jet collimation mechanism, bulk acceleration and deceleration in the jet, and the presence of a helical structure.

101.09 – The Solid Redshift Lower Limit of the Most Distant TeV-Emitting Blazar PKS 1424+240

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We present the newly determined redshift lower limit of the very-high-energy (VHE; $E > 100$ GeV) detected blazar PKS 1424+240. No VHE-detected blazar has shown solid spectroscopic evidence of being more distant. This redshift limit is firmly placed through the detection of Lyman forest features in new far-ultraviolet spectra from the Hubble Space Telescope/Cosmic Origins Spectrograph. The blazar is sufficiently distant so that past VHE observations sample historically large opacity values, extending beyond 4 if assuming low levels of extragalactic background light (EBL) and beyond 5 for high levels of EBL. We show the unexpected spectral shape of the absorption-corrected Compton peak, using the contemporaneous VERITAS and Fermi Large Area Telescope observations during the time of VHE emission discovery.

102 – HEAD Dissertation Prize Talk

102.01 – Winds of Change: The Physics of Accretion, Ejection, and X-ray Variability in GRS1915+105

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In the last twenty years, even as multiwavelength observations of black hole X-ray binaries have led to major advances, the microquasar GRS 1915+105 has continually challenged our understanding of the physics of accretion and ejection. With its relativistic jets, ionized winds, and myriad states of rapid, extreme variability, this remarkable black hole has been alternately seen as the black sheep of X-ray binaries and a Rosetta stone for black hole astrophysics. In this talk, I will present our efforts to use a decade of high-resolution X-ray spectroscopy of GRS 1915+105 to shed light on the processes that regulate its erratic behavior. I will highlight in particular the role of accretion disk winds on time scales ranging from seconds to years. Drawing on recent results, I will discuss the broader implications of these massive winds for the physics of inflows and outflows around black holes.

103 – Stellar Compact I: CVs, Isolated Neutron Stars, Planetary Nebula

103.01 – Mysteries and Discoveries from the Chandra Planetary Nebulae Survey (ChanPlaNS)

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Contributing teams: ChanPlaNS Team

Chandra observations of planetary nebulae (PNe) have ushered in a new wave of discoveries and mysteries in this class of evolved stars. The X-ray emission from PNe comes in two flavors: compact sources in the vicinity of the central star and extended sources that fill the nebular cavities generated during the PN formation process. The latter variety, called hot bubbles, are chemically-enriched with helium shell burning products (C, O, and Ne) and their temperatures seem to be regulated by heat conduction across the bubble-nebula interface or by charge-exchange with 'pickup ions' within the bubble. Perhaps more exotic are the compact sources at PN central stars. The (relatively hard) X-ray spectral energy distributions of all but one of these point sources cannot be explained by blackbody-like emission from the hot central stars but, instead, suggest the presence of even hotter thermal plasmas. The origin of this plasma emission may be coronae of binary companions, NLTE photospheric emission from the central (proto) white dwarfs, low-level accretion, or shocks in the chemically-enriched stellar wind. We are uncovering and investigating all of these phenomena via the Chandra Planetary Nebulae Survey (ChanPlaNS), a volume-limited archival and multi-cycle survey of planetary nebulae in the solar neighborhood. I present the highlights from our analysis and results and the promising prospects afforded by ChanPlaNS.

103.02 – Finding and Characterizing Compact Binaries via Their Optical Emission

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Contributing teams: Palomar Transient Factory

High-energy emission in the X- and Gamma-ray energy range is a standard tool for studying short-period binary systems containing a compact object. Many of these same sources also have rather distinctive optical variability. However because of their rarity most such sources have usually been identified first through their x- and gamma-ray emission. Large area sky synoptic sky surveys, such as the Palomar Transient Factory (PTF), now offer the possibility of identifying rare compact binaries via their optical variability. Among the discoveries enabled by PTF are: determining the precise position of a Fermi gamma-ray source that is a redback millisecond pulsar system; discovery of 8 new ultra-compact white-dwarf binary systems (AM CVn's) with periods less than 40 minutes, and discovery of a growing class of optically selected close magnetic binaries. We will briefly describe the PTF project and summarize the results on compact binaries.

103.03 – The E-Nova Project: New Insights into Mass Ejection in Nova Outbursts

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The E-Nova Project is a multiwavelength observing initiative with the primary goal of measuring the ejected masses of novae. The program leverages the capabilities of the upgraded Karl G. Jansky Very Large Array to obtain the highest quality radio light curves of novae to date. Radio emission in novae arises primarily in the ejected shell, and so directly traces its evolution over the course of the outburst. We complement the radio data with X-ray and optical observations to further constrain the dynamics of the ejecta. I will present an overview of the project and discuss some of our key results so far, including a surprisingly large ejected mass in the recurrent nova T Pyx and a direct constraint on the distance to the gamma-ray source Nova Mon 2012.

103.04 – Searching for MSPs with the Fermi Large Area Telescope

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Contributing teams: Fermi-LAT Collaboration

Since its launch in 2008, the Fermi Gamma-ray Space Telescope has been scanning the full sky every three hours, and has uncovered a large number of sources that are not associated with likely gamma-ray emitting counterparts. Investigation of the high-galactic latitude subset of these sources has led to the discovery of a large population of gamma-ray emitting millisecond pulsars, including a surprising number of black-widow systems. When searching for new MSP candidates in the Fermi unassociated source population, differences in the gamma-ray properties of the two types of systems can help discriminate between them, and provide guidance for follow-up pulsar searches in radio and other wavebands. We will discuss the methods used to define pulsar candidates from the Fermi data and the success rates of various follow-up techniques, and will explore what information the gamma-ray data can provide for searchers in other wavebands.

103.05 – X-ray Characterization of Fermi Gamma-ray Pulsars

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Contributing teams: Fermi Collaboration

We assess the X-ray behavior of the Fermi-LAT gamma-ray pulsars. Although most of the rotational energy of gamma-ray pulsars is released in the GeV range, significant X-ray emission is often detected. Indeed, 67 gamma-ray pulsars have been seen in X-rays (30 radio-loud, 19 radio-quiet and 18 millisecond pulsars). Although the coverage is uneven, we try to characterize such X-ray emission, in the 0.3-10 keV range, in order to assess the relationship, if any, between the pulsars' behavior in X and gamma-rays for the three different populations of Fermi pulsars. While the most energetic pulsars do have low ratios of gamma-ray to non-thermal X-ray energy flux (F_{gamma}/F_x), little can be said for the bulk of Fermi neutron stars, since pulsars with similar energetics have F_{gamma}/F_x spanning three decades. While the least scattered sample is that of the millisecond pulsars, among the young neutron stars detected by Fermi, radio-quiet pulsars show, on average, higher values of F_{gamma}/F_x and they appear definitely less scattered than the radio-loud pulsars.

103.06 – Magnetohydrodynamic Simulations of Oblique Pulsar Magnetospheres

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Studies of pulsar magnetospheres are usually carried out in the force-free limit, which assumes high magnetization of magnetospheric plasma, neglects plasma inertia and temperature, and retains only partial information about plasma velocity. We carried out time-dependent 3D relativistic magnetohydrodynamic (MHD) simulations of oblique pulsar magnetospheres that improve upon force-free by capturing plasma heating of magnetospheric current sheets, which are potential sites of gamma-ray emission, and by retaining the full plasma velocity information. We find rather low levels of magnetospheric dissipation, with no more than 10% of pulsar spindown energy dissipated within a few light cylinder radii, and the MHD spindown is consistent with that in force-free. While our MHD magnetospheres are qualitatively similar to the rotating split-monopole force-free solution at large radii, we find substantial quantitative differences with the split-monopole, e.g., the angular distribution of the pulsar wind can be more equatorially concentrated than the split-monopole and the velocity is modified by the emergence of reconnection flow directed into the current sheet.

103.07 – New Results on the Spectral Evolution of Magnetar Bright Bursts

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Contributing teams: GBM Magnetar Team

Magnetars are isolated neutron stars characterized by long spin periods (2-12 s) and large spin down rates, implying a very strong magnetic field, $B > 10^{14}$ G. Magnetars exhibit short bursts of hard X-/soft gamma-rays with luminosities ranging from 10^{37} to 10^{41} erg/s. The magnetar SGR J1550-5418 entered an extremely active bursting episode, starting on 2008 October 03 until 2009 April 17, during which Fermi Gamma-ray Burst Monitor (GBM) observed several hundred bursts from this source. Such wealth of bursts resulted in the largest catalog of detailed temporal and spectral results for SGR J1550-5418. Here, we discuss new results from time-resolved spectral analysis of the brightest bursts from this source. Our analysis, together with the comparison of our results with other magnetar bursts, enabled us to put strong constraints on the theories underlying the magnetar bursts emission mechanism.

103.08 – Mass and Radius Constraints Using Magnetar Giant Flare Oscillations

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We extend the study of oscillating neutron stars to include observed magnetic field strengths. The strong magnetic field will alter the equilibrium composition of the outer neutron star crust. We construct a new neutron star crust model which predicts nuclear masses with an accuracy very close to that of the Finite Range Droplet Model. The mass model for equilibrium nuclei also includes recent developments in the nuclear physics, in particular, shell corrections and an updated neutron-drip line. We perturb our crust model to predict axial crust modes and assign them to observed giant flare quasi-periodic oscillation (QPO) frequencies from SGR 1806-20. The QPOs associated with the fundamental and harmonic crust modes can be used to constrain magnetar masses and radii. We use these modes and the phenomenological equations of state from Steiner et al. to find a magnetar crust which reproduces observations of SGR 1806-20. We find magnetar crusts which match observations for various magnetic field strengths and values of entrainment of the free neutron gas in the inner crust. For a crust without a magnetic field we obtain the approximate values of $M = 1.35$ Msun and $R = 11.85$ km. For a magnetized crust with the surface dipole field of SGR 1806-20 we obtain the approximate values of $M = 1.25$ Msun and $R = 12.41$ km. If there is less entrainment of the free neutron gas the magnetar requires a larger mass and radius to reproduce observations.

103.09 – Anti-Glitch in the Magnetar 1E 2259+586

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One of the few windows we have into the inner-workings of neutron stars is to study spin-up glitches -- sudden increases in a neutron star's spin rate. We present a series of X-ray timing observations of the magnetar 1E 2259+586 obtained using the Swift X-ray Telescope which clearly show an 'anti-glitch' -- a sudden spin down of the neutron star. This anti-glitch was accompanied by an X-ray flux flare, and marked the start of a 90-day period of greatly enhanced spin down of the star, ended by a spin-up glitch of comparable amplitude. We argue that this anti-glitch had its physical origins in the interior of the neutron star, and can therefore be used as a new probe into the internal structure of high magnetic field neutron stars.

104 – Future Instrumentation And Missions in X-Ray Astronomy

104.01 – Future Development Trajectories for Imaging X-ray Spectrometers Based on Microcalorimeters

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Since their invention 30 years ago, the capability of X-ray microcalorimeters has increased steadily, with continual improvements in energy resolution, speed, and array size. Arrays of up to 1024 pixels have been produced, and resolution better than 1 eV at 1.5 keV has been achieved. These detectors can be optimized for the highest priority science, such as designing for the highest resolving power at low energies at the expense of dynamic range, or the greatest focal-plane coverage at the expense of speed. Three types of X-ray microcalorimeters presently dominate the field, each characterized by the thermometer technology. The first two types use temperature-sensitive resistors: semiconductors in the metal-insulator transition and superconductors operated in the superconducting-normal transition. The third type uses a magnetically coupled thermometer, and is at an earlier stage of development than the other two. The Soft X-ray Spectrometer (SXS) on Astro-H, expected to launch in 2015, will use an array of silicon thermistors with HgTe X-ray absorbers that will operate at 50 mK. Both the semiconductor and superconductor calorimeters have been implemented in small arrays. Kilopixel arrays of the superconducting calorimeters are being produced, and much larger arrays may require the non-dissipative advantage of magnetically coupled thermometers. I will project the development trajectories of these detectors and their read-out technologies and assess what their capabilities and limitations will be 10 - 20 years from now.

104.02 – The Future of X-ray Optics

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Contributing teams: SAO, PSU, MSFC, GSFC, ESTEC

Imaging in X-ray astronomy has resulted in enormous strides for astrophysics. But major advances over existing X-ray optics are required to keep pace with future capabilities across the electromagnetic spectrum. Current technologies – thermal forming, electroplating, and pore optics – offer improved effective area relative to previous flight missions, but do not achieve the simultaneous goals of lightweight, high resolution imaging, and affordable costs. We discuss the limitations of these technologies, as well as the potential of newer developments (such as adjustable optics, silicon optics, differential deposition, and others) to serve in an X-ray observatory in the next 10 – 20 years.

104.03 – The near vision (next 10 years) of X-ray astronomy in Japan

Takaya Ohashi¹

1. Tokyo Metropolitan Univ., Hachioji, Tokyo, Japan, Japan.

I will talk about plans of Japanese X-ray astronomy in the next 5 to 10 years. The L-class mission SPICA will hopefully proceed to phase-B this year, and there will be new opportunities for M-class and smaller missions. I will talk about the possible situation in Japan including the scope of X-ray missions after ASTRO-H.

105 – On the Detection of the Extragalactic Background Light

105.01 – Highlights of Recent Measurements and Constraints of the EBL Using Imaging Atmospheric Cherenkov Telescopes

Matthew Orr¹

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The photons constituting the extragalactic background light (EBL) interact, via electron-positron pair production, with very-high-energy (VHE) gamma rays (>10 GeV) propagating over cosmological distances. Blazars are some of the most readily detected sources of extragalactic VHE gamma rays observed by ground-based imaging atmospheric Cherenkov telescopes (IACTs). Imprinted on the spectra of these blazars is an absorption signature due to the EBL. These sources can therefore be used to constrain the intensity and spectral energy distribution (SED) of the EBL if one assumes basic knowledge of the intrinsic source emission. In this talk, I will review recent results from IACTs constraining the intensity and spectral shape of the EBL as well as the recent detection of an EBL imprint on the VHE spectra of blazars. I will also discuss the future prospects for EBL measurements and constraints using the current and next generation of IACTs.

105.02 – The Detection of the Cosmic Gamma-ray Horizon

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The first statistically significant detection of the cosmic gamma-ray horizon (CGRH) that is independent of any extragalactic background light (EBL) model is presented in this talk. The CGRH is a fundamental quantity in cosmology. It gives an estimate of the opacity of the Universe to very-high energy (VHE) gamma-ray photons due to photon-photon pair production with the EBL. The only estimations of the CGRH to date are predictions from EBL models and lower limits from gamma-ray observations of cosmological blazars and gamma-ray bursts. Here, we present synchrotron/synchrotron self-Compton models (SSC) of the spectral energy distribution of 15 blazars based on (almost) simultaneous observations from radio up to the highest energy gamma-rays taken with the Fermi satellite. These synchrotron/SSC models predict the unattenuated VHE fluxes, which are compared with the observations by imaging atmospheric Cherenkov telescopes. This comparison provides an estimation of the optical depth of the EBL, which allows a derivation of the CGRH through a Monte Carlo analysis that is EBL-model independent. We find that the observed CGRH is compatible with the current knowledge of the EBL. We conclude showing that the detection of the CGRH allows us to estimate the expansion rate of the Universe from gamma-ray attenuation.

105.03 – Secondary TeV Gamma Rays from Distant Blazars, and Extragalactic Background Light

Alexander Kusenko^{1, 2}

1. *UCLA, Los Angeles, CA, United States.* 2. *IPMU, Tokyo, Japan.*

Gamma-ray spectra of distant blazars are explained extremely well by the secondary gamma rays produced in line-of-sight interactions of cosmic rays with background photons (CMB and EBL). Both high and low EBL models are consistent with this explanation of the gamma-ray data, but some sensitivity to the level of EBL can be used to measure the level of EBL in the future.

105.04 – The Imprint of the Extragalactic Background Light in the Gamma-ray Spectra of Blazars

Marco Ajello¹, Rolf Buehler³, Anita Reimer²

1. *SSL, Berkeley, Berkeley, CA, United States.* 2. *Innsbruck University, Innsbruck, Austria.* 3. *Desy Zeuthen, Berlin, Germany.*

Contributing teams: Fermi-LAT Collaboration

The light emitted by stars throughout the history of the Universe is encoded in the intensity of the extragalactic background light (EBL). Knowledge of the EBL is important for understanding the nature of star formation and galaxy evolution. Direct measurements of the EBL are very difficult due to the intense zodiacal light and the Galactic foreground emission. High-energy gamma rays may interact with photons of the EBL and generate positron-electron pairs. This introduces an attenuation feature in the spectra of distant gamma-ray sources that has been used in the past to set upper limits on the opacity of the Universe and the energy density of the EBL. In this talk, we will report the first detection of an absorption feature seen in the combined spectra of a sample of gamma-ray blazars detected by the Fermi Large Area Telescope (LAT) out to a redshift of $z > 1.6$. This feature is caused by attenuation of gamma rays by the EBL at optical to UV frequencies, and points to a minimal level of EBL, consistent with the observed star formation rate and with low-opacity EBL models. We will present the Fermi observations and discuss the implications for the generation of a diffuse UV background at high redshifts. The prospects for a refined measurement of the EBL extending to redshifts higher than $z \sim 1.6$ will also be discussed.

105.05 – Extragalactic Background Light up to the Epoch of Cosmic Reionization

Yoshiyuki Inoue¹, Susumu Inoue², Masakazu A. Kobayashi⁵, Ryu Makiya⁴, Yuu Niino³, Tomonori Totani⁴, Yasuyuki Tanaka⁶

1. *KIPAC/SLAC/Stanford, Menlo Park, CA, United States.* 2. *MPIK, Saupfercheckweg, Heidelberg, Germany.* 3. *NAOJ, Mitaka, Tokyo, Japan.* 4. *Kyoto University, Kyoto, Kyoto, Japan.* 5. *Ehime University, Matsuyama, Ehime, Japan.* 6. *Hiroshima University, Hiroshima, Hiroshima, Japan.*

We present a new model of the extragalactic background light (EBL) and corresponding gamma-gamma opacity for intergalactic gamma-ray absorption from $z=0$ up to $z=10$, based on a semi-analytical model of hierarchical galaxy formation that reproduces key observed properties of galaxies at various redshifts. Including the potential contribution from Population III stars in a simplified way, the model is also broadly consistent with available data concerning cosmic reionization, particularly the Thomson scattering optical depth constraints from WMAP. The horizon energy at which the gamma-ray opacity is unity does not evolve strongly beyond $z \sim 4$ and approaches ~ 20 GeV. The contribution of Population III stars is a minor fraction of the EBL at $z=0$, and is also difficult to distinguish through gamma-ray absorption in high- z objects, even at the highest levels allowed by the WMAP constraints. Nevertheless, the attenuation due to Population II stars should be observable in high- z gamma-ray sources by telescopes such as Fermi or CTA and provide a valuable probe of the evolving EBL in the rest-frame UV.

106 – Public Policy; Working Internationally

106.01 – The Atacama Large Millimeter/Submillimeter Array (ALMA) - A Successful Three-Way International Partnership Without a Majority Stakeholder

Paul A. Vanden Bout¹

1. NRAO, Charlottesville, VA, United States.

The Atacama Millimeter/Submillimeter Array (ALMA) is the largest ground-based astronomical facility built to date. Its size and challenging site required an international effort. This talk presents the partnership structure, management challenges, current status, and examples of early scientific successes.

106.02 – Building International Space Observatories

Harvey Tananbaum¹

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

In this brief presentation I will focus on international collaborations for building x-ray observatories. Two primary approaches seem relevant for discussion: 1. Contribution of an instrument by one Agency to a mission led by another 2. Substantial participation by 2 or more Agencies in designing and building an Observatory - close to equal partnerships. Most of our experience in x-ray astronomy falls into the first category, and I will illustrate by briefly summarizing Chandra. The second case will be assessed by reviewing the community's and Agencies' efforts on the International X-ray Observatory (IXO). What can we distill from the successes and difficulties encountered over the past several years? Thoughts about how we might proceed in the future will be shared during the subsequent Panel Discussion. Independent of the development approach, we seem to have general agreement that the bulk of the observing time should be open to scientists world-wide through Peer Review to optimize the science return.

106.03 – NASA's Astrophysics Program

Paul L. Hertz¹

1. NASA Headquarters, Washington, DC, United States.

The environment in which NASA and other Government agencies are operating is constantly changing. It is significantly different from the environment assumed by the recent 2010 Decadal Survey. NASA has described its plans for responding to the Decadal Survey in its 2012 Astrophysics Implementation Plan (<http://science.nasa.gov/astrophysics/documents/>). The NASA Astrophysics Division plans to: Enable the science and priorities identified by the Decadal Survey with new activities as well as through ongoing missions, including large missions, medium missions, and Explorers; Invest in the Astrophysics Research Program for developing the science cases and technologies of new missions and for maximizing the scientific return from operating missions; Engage in effective international and interagency partnerships that leverage NASA resources and extend the reach of our science results; Conduct studies of WFIRST and candidate probes that derive from the activities prioritized in the Decadal Survey and are responsive to the Decadal Survey science questions; Be prepared to begin a strategic mission, subject to the availability of funds, which follows from the Decadal Survey and is launched after the James Webb Space Telescope.

108 – AGN Structure and Variability

108.01 – The Global Implications of the Hard X-ray Excess in Type 1 AGN

Malachi Tatum¹, T. Jane Turner¹, Lance Miller², James Reeves^{3, 1}

1. UMBC, Baltimore, MD, United States. 2. University of Oxford, Oxford, England, United Kingdom. 3. Keele University, Keele, England, United Kingdom.

Suzaku observations of 1H 0419-577 and PDS 456, both type 1 AGN, revealed a marked 'hard excess' of flux above 10 keV, likely due to the presence of a Compton-thick absorber covering a large fraction of the continuum source. The discovery is intriguing, given the clear view to the optical BLR in type 1 objects. These results motivated an exploratory study of the hard excess phenomenon in the local type 1 AGN population, using the Swift Burst Alert Telescope (BAT). We selected radio quiet type 1 - 1.9 AGN from the 58-month BAT catalog and cross-correlated them with the holdings in the Suzaku public archive. The hardness of the X-ray spectrum, combined with measurements of the equivalent width of Fe K α emission suggest that type 1 X-ray spectra are shaped by an ensemble of Compton-thick clouds, partially covering the continuum. I discuss our methodology, the observational findings and the possible location of the Compton-thick gas.

108.02 – Ten-year History of Warm Absorbers in Mrk 290: COS and FUSE Observations

Shuinai Zhang¹, Li Ji¹, Tim Kallman², Yangsen Yao³, Qiusheng Gu⁴, Cynthia S. Froning³

1. Purple Mountain Observatory, Nanjing, Jiangsu, China. 2. Goddard space flight center, NASA, Greenbelt, MD, United States. 3. Department of Astrophysical and Planetary Sciences, University of Colorado, Boulder, CO, United States. 4. School of Astronomy and Space Science, Nanjing, Jiangsu, China.

We analyze intrinsic UV absorptions in Mrk 290, and find that they are from the same warm absorbers (WAs) detected in the X-ray band. The one-to-one relation of WAs in the two bands was proved by applying XSTAR generated photoionization models to HST/COS and FUSE spectra. They have similar gas properties and the same location of torus. We explore the history of WAs over the period from 2000 to 2009. Part of the absorption over ten years is identified as the same one, which was slowly expanding. And the variability of its column density seems to be related to the changes of ionizing luminosity. The result suggests that the central engine in Mrk 290 may keep blowing gas out from the inner side of torus at the same velocities.

108.03 – Simulating the Spectra of BAL QSOs with a Biconical Wind

Nicholas Higginbottom¹, Knox S. Long², Christian Knigge¹, Stuart Sim³

1. University of Southampton, Southampton, United Kingdom. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. Queens University, Belfast, Northern Ireland, United Kingdom.

Outflows are a fundamental part of understanding the structure of AGN and their interactions with both the host galaxy, and their local extra galactic environment. In addition to radio jets, there is increasing evidence for the existence of disk winds in AGN, most compellingly in the case of broad absorption line quasars (BALQSOs). Such winds have also been suggested as the source of the broad emission line region (BELR), narrow absorption line region (NALR) and even the narrow emission line region (NLR). Given the potential importance of this phenomenon for both AGN unification and feedback, a proper understanding of disk winds in the AGN context is vital. Extensive modeling of the effect of such flows on the X-ray spectrum of AGN has already been carried out, and we present initial results of a complementary project modelling the UV features of BALQSOs. Here we describe our attempt to model the spectra of BALQSOs in assuming a bi-conical wind emerging from the disk or torus. We are able to produce spectra that qualitatively resemble the spectra of BALQSOs as long as the X-ray luminosity of the quasar does not exceed 10^{44} ergs/s. Our simulations provide insight into the physical conditions required to produce BAL QSOs. We find that the region where the X-ray features are produced is unlikely to be co-located with the region where the UV lines are generated. This work demonstrates the need for significant mass loss in disk winds in order to reproduce the observed spectral features of AGN and starts to place useful limits on the kinetic luminosity of such flows.

108.05 – A Half-Megasecond X-ray Study of the ULIRG Mrk 231

Stacy H. Teng¹, Sylvain Veilleux², David Rupke³

1. NASA/GSFC, Greenbelt, MD, United States. 2. University of Maryland, College Park, MD, United States. 3. Rhodes College, Memphis, TN, United States.

Gas-rich galaxy merging at high redshifts may trigger major starbursts, lead to the formation of elliptical galaxies, and account for the formation and growth of supermassive black holes. In this merger-driven evolutionary scenario, the system evolves from a completely obscured ultraluminous infrared galaxy (ULIRG), then gives rise to a dusty quasar, and then finally an unobscured optical quasar once the obscuring gas and dust are dispersed. Powerful winds, driven by the central quasar or the surrounding starburst, have been invoked to stop the growth of both the central black hole and the spheroidal component to explain the tight black hole-spheroid mass relation. Recently, a powerful outflow (~ 1000 km/s) has been discovered in the nearest post-merger quasar and ULIRG Mrk 231. This wide-angled outflow extends over several kpc and it is thought to be a quasar wind; this may be evidence that quasar mechanical feedback is important and can transform gas-rich mergers into red and dead galaxies. We present our analysis of over 500 ks of Chandra ACIS-S new and archival data on the X-ray faint nebula surrounding the quasar.

108.06 – Chandra and VLA Observations of Supermassive Black Hole Outbursts in M87 and Implications for Feedback in Early-Type Galaxies

William R. Forman¹, Eugene Churazov^{2, 3}, Christine Jones¹

1. SAO-CfA, Cambridge, MA, United States. 2. MPA, Garching, Germany. 3. IKI, Moscow, Russian Federation.

We discuss the effects of supermassive black hole (SMBH) outbursts on the hot atmospheres surrounding massive galaxies as observed with X-ray and radio observations. We initially focus on a detailed study of outbursts from the supermassive black hole in M87 using Chandra and VLA observations. We model the outburst that created the classical Mach 1.2 shock seen in Chandra images and derive the characteristic energy (5×10^{57} ergs), duration (2 Myrs), and age (12 Myrs) of the outburst from numerical models. We review the outburst history of the SMBH in M87 over the past ~ 100 Myr. We discuss the implications of the outbursts for feedback in typical early-type galaxy atmospheres.

108.07 – Do Unification Models Explain the X-ray Properties of Radio Sources?

Belinda J. Wilkes¹, Joanna Kuraszkiwicz¹, Martin Haas², Peter Barthel³, Steven P. Willner¹, Christian Leipski⁴, Diana Worrall⁵, Mark Birkinshaw⁵, Robert R. Antonucci⁶, Matthew Ashby¹, Rolf Chini⁷, Giovanni G. Fazio¹, Charles R. Lawrence⁸, Patrick M. Ogle⁹, Bernhard Schulz¹⁰

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Chandra observations of a complete, flux-limited sample of 38 high-redshift ($1 < z < 2$), low-frequency-radio selected (and so relatively unbiased in orientation), 3CRR radio sources (21 quasars, 17 narrow line radio galaxies, NLRGs) support Unification models and lead to estimates of the covering factor as a function of orientation. The sample was chosen to minimize the range of intrinsic luminosity and evolutionary state and maximize the range of nuclear orientation. The quasars, with high radio core-fraction, have soft X-ray hardness ratios indicating low obscuration, as expected for their face-on orientation. Half the NLRGs, which have lower radio core fraction, have hard X-ray hardness ratios consistent with a more edge-on orientation. The other half have a range of X-ray hardness ratios, very weak X-ray emission and multi-wavelength properties consistent with a view through Compton thick material. The X-ray intrinsic absorption column density correlates with the radio core fraction, which is an orientation indicator. A general picture of the absorbing material includes a Compton thick obscuring disk/torus extending $\sim 15^\circ$ from the midplane, additional and lower column density material extending for another $\sim 15^\circ$ with the column density decreasing away from the mid-plane. The remaining $\sim 60^\circ$ is largely unobscured. We conclude that: - radio selection finds the largest fraction of (\sim all) heavily obscured active galaxies (AGN), within the 10% radio-loud population - nuclear orientation is important in determining the observed properties of AGN - high quality and/or multi-wavelength data are required to understand the nature of a source and to determine reliable properties - the spectral energy distributions of this sample potentially will constrain competing models for the obscuring nuclear material in AGN.

108.08 – Inclination-Dependent Active Galactic Nucleus Flux Profiles From Strong Lensing of The Kerr Spacetime

Bin Chen¹, Xinyu Dai¹, Edward A. Baron¹, Ronald Kantowski¹

1. University of Oklahoma, Norman, OK, United States.

Recent quasar microlensing observations have constrained the X-ray emission sizes of quasars to be about 10 times the gravitational radii of the quasars' central supermassive black holes, an order of magnitude smaller than optical emission sizes. We have developed a ray-tracing code using the Kerr metric to study the effects of strong lensing by the rotating black hole on the optical and X-ray emission. We find that Kerr lensing can change observed X-ray-to-optical flux ratios by a factor of 10 for normal quasars and another factor of 10 for broad absorption line quasars (BALs) and obscured quasars, depending on the inclination angle and the corona geometry. We find that the spectrum slope parameter α_{OX} can differ by ~ 0.2 between normal and broad absorption line quasars and, consequently that the intrinsic X-ray absorption of BALs can be significantly underestimated by ignoring Kerr strong lensing. We also find that Kerr lensing can significantly change the observed X-ray microlensing light curves. We conclude that Kerr lensing is inevitably important for X-ray emission of quasars, and that it should be possible to distinguish between various corona geometries and constrain important parameters such as inclination angles and black hole spins by combining Kerr strong lensing and microlensing effects.

108.09 – Charged Off-equatorial Structures in Astrophysical Gravitational and Magnetic Fields

Jiri Kovar¹, Petr Slany¹, Vladimir Karas², Zdenek Stuchlik¹

1. Institute of Physics, Silesian University in Opava, Opava, Czech Republic. 2. Astronomical Institute, Academy of Sciences, Prague, Czech Republic.

Results of our recent studies suggest a possibility of existence of halo (off-equatorial) electrically charged toroidal structures (thick discs) and polar caps circling in axially symmetric backgrounds of central objects (compact stars, black holes, etc.) endowed with electromagnetic fields. Along with the existence of the halo structures we have also found equatorial tori with cusps enabling outflows of matter from the torus, without the presence of strong gravity, i.e., also in the Newtonian regime. These phenomena represent qualitatively new consequence of the interplay between gravity and electromagnetism, and can provide an insight into processes determining vertical structure of dusty tori surrounding accretion discs. Some of these results are summarized also in the paper accepted for the publication in The Astrophysical Journal Supplement, scheduled for the March 2013, Volume 205.

108.10 – First Statistical Tests for Clumpy Torii Models: Constraints from RXTE Monitoring of Seyfert AGN

Alex Markowitz^{1, 2}, Mirko Krumpe^{3, 1}, Robert Nikutta⁴

1. UC, San Diego, La Jolla, CA, United States. 2. Karl Remeis Sternwarte, Bamberg, Germany. 3. European Southern Observatory, Garching bei Muenchen, Germany. 4. Universidad Andres Bello, Santiago, Chile.

We present an analysis of multi-timescale variability in line of sight X-ray absorbing gas as a function of optical classification in Seyfert AGN in order to derive the first statistical constraints for *clumpy* absorbing torus models. We use the vast archive of Rossi X-ray Timing Explorer monitoring of dozens of Sy 1-1.5s and Compton-thin Sy 1.9-2s, containing sustained monitoring campaigns spanning from days to over a decade for individual objects and totaling over 220 'object \times years'. We search for discrete absorption events due to clouds of full-covering, neutral or mildly-ionized gas with columns approx. 10^{22-24} cm⁻² transiting the line of sight. Using hardness ratio and photon index light curves and time-resolved spectroscopy, we confirm 11 occultation events in eight objects, including three previously published events. Peak column densities span $2.5-19 \times 10^{22}$ cm⁻², i.e., there are no full-covering Compton-thick events in our sample. Event durations span from 1 day to 6 months. We infer the absorbers' radial distances from the black hole, assuming Keplerian motion, to be roughly commensurate with the locations of IR-emitting dusty torii in three objects. In five objects, the X-ray clumps' locations span radii commensurate with the outer portions of optical/near-IR Broad Line Regions (BLR) outside the BLR by up to factors of 2-3. In one object, the X-ray clump is commensurate with the BLR. We discuss implications for cloud distributions in the general context of clumpy torus models and we calculate probabilities for observing obscuration in a given optical class.

108.11 – Tackling the Soft X-ray Excess in AGN with Variability Studies

Anne M. Lohfink¹, Christopher S. Reynolds¹, Richard Mushotzky¹, Michael Nowak²

1. University of Maryland, College Park, MD, United States. 2. MIT, Kavli Institute for Astrophysics, Cambridge, MA, United States.

The origin of the soft X-ray excess in AGN has been a mystery ever since its discovery. We present how the time variability of this spectral component can point towards its origin. Using the powerful technique of multi-epoch fitting, we study how the soft excess in a given object depends on other parameters of the continuum and the accretion disk possibly hinting at its nature. As an example, we present results from this technique applied to the Seyfert galaxy Mrk 841, the source in which the soft excess was originally discovered. We study 3 XMM and 2 of the Suzaku pointings available and find that the source displays an impressive variability in the soft X-ray band on the timescale of years. We explore several common soft excess models and their ability to physically consistently explain this spectral variability. We find that the shape and strength of the soft excess correlates with the general X-ray continuum shape and flux, implying a connection between the two. Possible scenarios for such a connection will be discussed.

108.12 – What is Truly the Relationship Between Jet, Accretion Disk and BLR Intensity Changes in FSRQs?

Giovanni Fossati¹

1. Rice Univ., Houston, TX, United States.

Studies of the relationship between variations in the broad emission lines intensity are slowly beginning to bear fruit and the interpretation of their results (e.g. correlations in time and intensity) requires to look more in depth at the relationship between the various 'radiative signals', some of which may be responsible for causing variations in other components, examples being BLR radiation seeding EC in the jet, disk emission increasing BLR power, or as recently discussed jet emission ionizing part of the BLR. Because the jet 'blob' moves nearly at the same speed of the 'signals', the actual relationships are somewhat at odds with the naive intuition. I will present results of our study of the observational implications/appearance of variations emerging in different components and discuss the implications for the interpretation of recent novel observational work.

108.13 – Probing the Evolving X-ray Sources of Accreting Black Holes

Dan Wilkins¹

1. Institute of Astronomy, University of Cambridge, Cambridge, United Kingdom.

Material spiralling into black holes powers some of the most luminous objects we see in the Universe; AGN and galactic black hole binaries. X-rays are emitted from a corona of energetic particles around the black hole and are seen to reflect off of the accretion disc. As well as being impressive objects in their own right, the black holes in AGN can emit such large amounts of energy that they are important in governing the growth of galaxies and clusters. Through detailed analysis of the observed reflection features in the X-ray spectrum and the variability of the detected emission showing reverberation time lags between the directly observed continuum and the reflection, it is possible to detect the emission from material right down to the innermost stable orbit around the black hole. Comparing these observations to the results of general relativistic ray tracing simulations allows them to be analysed in the context of the geometry of the X-ray emitting region and it has been possible to constrain the locations of the X-ray sources in a number of AGN including 1H 0707-495, IRAS 13224-3809 and MCG-6-30-15. With high quality data from long X-ray observations of these sources, it has, for the first time, been possible to follow the evolution of the coronal X-ray source as the luminosity of the source goes up and down. We are able to find evidence that the size and other properties of the X-ray source changes on the timescale of a few hours, giving rise to the extreme variability seen in these sources with the source increasing in size as the luminosity increases. Such detailed analysis of observations (both of spectra and variability) and studies of how the X-ray source is changing is paving the way to the science that will be possible with the next generation of X-ray instruments (NuStar and Astro-H) and will allow us to understand the processes at work in the innermost regions of accreting black holes, releasing energy from the accretion flow to power some of the brightest objects in the Universe.

108.14 – Exploring Plasma Evolution During Flares from Sgr A*

Salome Dibi¹, Sera Markoff¹, Renaud Belmont², Julien Malzac², Michael Nowak³, Frederick K. Baganoff³, Joseph Neilsen⁴

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We present a new way of describing the flares occurring in the Galactic Center supermassive black hole Sgr A*. The flares originate within ~ 10 Schwarzschild radii from the black hole, a region we model as a single zone with fully time-dependent calculations. All relevant radiative processes are taken into account in both the evolution of the radiating lepton distribution and in the resulting spectra. The computation of the particle distribution includes also prescriptions for particle acceleration/heating. We model the multiwavelength spectra of Sgr A* in both the quiescent and flaring states, investigating the physical changes necessary to go from one state to another and to generate X-ray lightcurves of the flares. We compare our results with flare data from the new 3Ms Chandra XVP campaign on the Galactic Center completed in 2012, and discuss new constraints on the physics driving the flares in Sgr A*. We acknowledge the participation of the Sgr A* XVP collaboration (sgra-star.com).

108.15 – Modeling X-ray Absorbers in AGNs with MHD-Driven Accretion-Disk Winds

Keigo Fukumura¹, Demosthenes Kazanas², Chris R. Shrader², Francesco Tombesi^{2, 3}, John Contopoulos⁵, Ehud Behar⁴

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We have proposed a systematic view of the observed X-ray absorbers, namely warm absorbers (WAs) in soft X-ray and highly-ionized ultra-fast outflows (UFOs), in the context of magnetically-driven accretion-disk wind models. While potentially complicated by variability and thermal instability in these energetic outflows, in this simplistic model we have calculated 2D kinematic field as well as density and ionization structure of the wind with density profile of $n \sim 1/r$ corresponding to a constant column distribution per decade of ionization parameter. In particular we show semi-analytically that the inner layer of the disk-wind manifests itself as the strongly-ionized fast outflows while the outer layer is identified as the moderately-ionized absorbers. The computed characteristics of these two apparently distinct absorbers are consistent with X-ray data (i.e. a factor of ~ 100 difference in column and ionization parameters as well as low wind velocity vs. near-relativistic flow). With the predicted contour curves for these wind parameters one can constrain allowed regions for the presence of WAs and UFOs. The model further implies that the UFO's gas pressure is comparable to that of the observed radio jet in 3C111 suggesting that the magnetized disk-wind with density profile of $n \sim 1/r$ is a viable agent to help sustain such a self-collimated jet at small radii.

108.16 – First Results from the NuSTAR AGN Physics Program

Laura Brenneman¹, Felix Fuerst⁴, Giorgio Matt², Dominic Walton⁴, Grzegorz M. Madejski³, Andrea Marinucci^{2, 1}, Martin Elvis¹, Guido Risaliti^{10, 1}, Fiona Harrison⁴, Daniel Stern⁵, Steve Boggs⁶, Finn Christensen⁷, William W. Craig⁸, William Zhang⁹

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Contributing teams: NuSTAR Team

The Nuclear Spectroscopic Telescope Array (NuSTAR, launched June 2012) is revolutionizing our knowledge of the physics at work in active galactic nuclei (AGN). With its high collecting area, focusing optics and low background from 3-79 keV, NASA's newest X-ray observatory is providing an unprecedented look at the spectral and timing properties of AGN in this energy range, which have been notoriously difficult to access. NuSTAR has observed several AGN to date simultaneously with XMM-Newton, Suzaku and/or Swift for the purposes of understanding their coronal properties (e.g., plasma temperature, optical depth) and measuring the spins of their supermassive black holes. We present the first results from these observing campaigns, highlighting the spectral and timing analysis of the bright, nearby AGN IC 4329A, NGC 4151, NGC 1365 and MCG--6-30-15. These are the highest signal-to-noise datasets ever obtained across the 0.2-79 keV energy band for these three sources, allowing us to cleanly deconvolve the X-ray continuum, absorption and reflection components in each galaxy for the first time via time-averaged and time-resolved spectroscopy.

108.17 – NuSTAR Observations of Blazar Mkn 421

Mislav Balokovic¹, Marco Ajello², Roger D. Blandford², Steven E. Boggs³, Kristen Boydston¹, Finn Christensen⁴, William W. Craig³, Amy Furniss⁵, Paolo Giommi⁶, Charles J. Hailey⁷, Masaaki Hayashida², Brian Humensky⁷, Yoshiyuki Inoue², Jason Koglin⁷, Greg M. Madejski², David L. Meier⁸, Patrick M. Ogle¹, Matteo Perri⁶, Simonetta Puccetti⁶, Anthony C. Readhead¹, Daniel Stern⁸, Gianpiero Tagliaferri⁹, C. M. Urry¹⁰, Ann E. Wehrle¹¹, William Zhang¹², Thomas Nelson¹³, David Paneque¹⁴

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We present NuSTAR observations of the famous blazar Mkn 421. The object was observed during the NuSTAR's calibration phase in July 2012, contemporaneous with increased activity seen with Fermi. Since January 2013, it has been a subject of a five-month multi-wavelength campaign consisting of three pointings per month, strictly simultaneous with observations with the Veritas and MAGIC TeV telescopes, aimed at characterization of any correlated variability. Mkn 421 was clearly detected up to highest NuSTAR energies with a spectrum that is a gradually steepening power law, with no evidence for hardening at high energies. Significant variability spanning almost an order of magnitude in flux was seen between the observations, and flux changes by a factor of 3 have been observed within a single 12-hour period. The flux variability was correlated with spectral variations, such that the spectrum was softer when the object was fainter. This behaviour is consistent with previous soft X-ray observations in same flux range. The unprecedented data quality for the faint non-flaring state and the extension of high sensitivity above 10 keV allow us to study the distribution of radiating particles in the context of standard leptonic models.

108.18 – Probing AGN Shutdown on the Shortest Timescales

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Contributing teams: Galaxy Zoo

Extended Emission Line Regions provide important clues to the radiative and kinematic history of galactic nuclei. We present results from recent narrow-band Hubble images of a sample of 'voorwerpje' galaxies which, like Hanny's Voorwerp, were identified by Galaxy Zoo citizen scientists and provide some of the most detailed clues as to the behavior of galaxies immediately (<100 kyr) after the transition from a bright quasar mode to a state that is relatively deficient in ionizing radiation. These complicated systems show evidence of recent disturbance, loops and filaments, and misaligned ionization cones. These elements point to a likely transition from a radiative state to a kinematic one, and a possible evolutionary role for a massive black hole binary. New Chandra observations will be critical to explaining the nature of these complicated systems.

108.19 – An XMM View of 3C 411

Allison Bostrom¹, Christopher S. Reynolds¹, Francesco Tombesi¹

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We present XMM-Newton observations of the broad-line radio galaxy 3C 411. After fitting various spectral models, an absorbed double-power law model is found to be the most plausible description of the data. While the softer power-law component is entirely consistent with that found in Seyfert galaxies (and hence likely originates from a disk corona), the additional power law component is very hard; amongst the AGN zoo, only flat-spectrum radio quasars have such hard spectra. Together with the very flat radio-spectrum displayed by this source, we suggest that it should be classified as a FSRQ.

109 – AGN Surveys and Catalogs

109.01 – Photoionized X-ray Emission

Timothy R. Kallman¹

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Spectra in the 0.1 – 10 keV energy range reveal that absorption by partially ionized gas is common in active galaxies and X-ray binaries. Modeling is key for understanding the implications of such spectra for the configuration of gas in these systems, and current models have been successfully applied to spectra from many objects. Photoionized X-ray emission spectra have been studied less thoroughly. These spectra are of interest partly because they must inevitably affect the absorption spectra and also as tests of the geometrical distribution of gas near compact objects. The modeling code xstar can be applied to both types of spectra, although an efficient treatment of emission associated with bound-bound radiative excitation was not included until recently. In this poster I will describe these recent changes and illustrate application of xstar to sample X-ray spectra.

109.02 – The Average 0.5-200 keV Spectrum of AGNs at $z \sim 0$

David R. Ballantyne¹

1. Georgia Institute of Technology, Atlanta, GA, United States.

The X-ray spectra of AGNs span nearly three decades in energy and are comprised of many separate components: a power-law with a high energy cutoff, reflection from the accretion disk as well as distant material, and, in many cases, a soft excess. Aside from a small number of bright sources observed with BeppoSAX, the full energy range of AGN spectra has only been studied in piecemeal by a fleet of X-ray observatories that can only focus on a small part of the entire spectrum. Therefore, while catalogues of the spectral properties of hundreds of AGNs have been published in different energy bands, these results are isolated from one another and a clear picture of the broadband spectral properties of typical AGNs remains elusive. In this work, we make use of the $z \sim 0$ X-ray luminosity functions of AGNs in the 0.5-2 keV, 2-10 keV, 3-20 keV, 15-55 keV and 14-195 keV bands to construct the spectral model of an average AGN that can simultaneously account for all 5 luminosity functions. Enhanced iron abundances, disk reflection, and the presence or absence of the X-ray Baldwin Effect are considered, along with the traditional parameters of photon index and cutoff energy. Applications to X-ray background modelling and AGN physics are discussed.

109.03 – Full Spectral Survey of Active Galactic Nuclei in the Rossi X-ray Timing Explorer Archive

Elizabeth Rivers¹, Alex Markowitz¹, Richard E. Rothschild¹

1. UCSD, La Jolla, CA, United States.

We have analyzed spectra for all active galactic nuclei in the Rossi X-ray Timing Explorer (RXTE) archive. We provide fluxes and exposure times for 150 AGN in the archive and present long-term average values of absorption, Fe line equivalent width, Compton reflection and photon index, as well as calculating fluxes and luminosities in the 2-10 keV band for 100 AGN with sufficient brightness and overall observation time to yield high quality spectral results. We compare these parameters across the different classifications of Seyferts and blazars and improve upon previous surveys of the hard X-ray energy band in terms of accuracy and sensitivity. Our distributions of photon indices for Seyfert 1's and 2's are consistent with the idea that Seyferts share a common central engine, however our distributions of Compton reflection hump strengths do not support the classical picture of absorption by a torus and reflection off a Compton-thick disk with type depending only on inclination angle. We conclude that a more complex reflecting geometry such as a combined disk and torus or clumpy torus is likely a more accurate picture of the Compton-thick material. By comparing Fe line EW's to Compton reflection hump strengths we have found that on average 40% of the Fe line arises in Compton thick material, however this ratio was not consistent from object to object and did not seem to be dependent on optical classification. This survey is meant to provide a baseline for future analysis with respect to the long-term averages for these sources and to explore differences and similarities across the different types of AGN.

109.05 – Stripe 82 X: X-ray Survey of SDSS Stripe 82

Stephanie M. LaMassa¹, C. M. Urry¹, Eilat Glikman¹, Nico Cappelluti², Andrea Comastri², Hans Boehringer³, Gordon T.

Richards⁴, Stephen S. Murray^{5, 6}

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We present the preliminary results of a large area X-ray survey overlapping SDSS Stripe 82 ("Stripe 82 X"), a region rich in multi-wavelength coverage. Combining archival Chandra and XMM-Newton data, as well as proprietary XMM observations, the current X-ray coverage of Stripe 82 is $\sim 17 \text{ deg}^2$, complementing the parameter space explored by previous deep, small area and moderate area X-ray surveys. We find that prior to spectroscopic follow-up, we find nearly as many high luminosity AGN as the 10 deg^2 X-ray survey of Bootes, at all spectroscopic redshifts and in the distant universe ($z > 2$). Our X-ray source list is matched with SDSS, WISE and UKIDSS, revealing > 100 X-ray sources lacking optical counterparts but with robust infrared detections, which are candidates for elusive obscured quasars at high redshifts.

109.06 – The Northern Galactic Cap AGN from the 58-month BAT Catalogue: A Comprehensive X-ray Spectral Study

Ranjana Vasudevan¹, W. N. Brandt², Richard Mushotzky¹, Lisa M. Winter⁴, Wayne H. Baumgartner⁵, Taro Shimizu¹, John A.

Nousek², Donald P. Schneider², Poshak Gandhi³

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The all-sky hard X-ray Swift/BAT survey has provided the most complete census of local AGN activity to date, unbiased to all but the most heavy absorption levels. Continual monitoring in the 14–195 keV band has allowed the assembly of hard X-ray detected AGN catalogues after 9, 22, 36, 58 and 70 months of operation, increasing the sample size by probing to fainter fluxes. The seminal study of Winter et al. (2009) presented a comprehensive X-ray analysis of the AGN in the 9-month catalogue, providing their absorption and luminosity distributions, characterising the spectral shape for each source in the catalogue, and

allowing the determination of sample-wide properties for an unbiased AGN sample. We present a timely revision of this exercise for the latest publicly available 58-month BAT catalogue (flux limit 4×10^{-12} erg/s/cm² in the 14-195 keV band), focusing on the Northern Galactic Cap ($b > 50$ degrees). This sky area has excellent potential for further dedicated study due to a wide range of multi-wavelength data that are already available, and we propose it as a low-redshift analogue to the 'deep field' observations of AGN at higher redshifts. We consistently fit all the 100 objects in this sky region with a suite of models to determine the best fitting column densities, luminosities and spectral features (Iron lines, soft excesses and warm absorber edges). Comparison with previous works on the 9-month and 36-month catalogues now allows a better understanding of whether the deepening exposure of the BAT catalogue uncovers progressively different AGN properties. We find that ~60% of the sample is absorbed above $\log N_{\text{H}} = 22$, 9% is Compton thick, and Compton reflection is significant for the sample overall (average reflection amplitude = 2.7). The sample is complete down to fluxes 4 times fainter than the 9-month catalogue in the 2–10 keV band. We emphasise the utility of this Northern Galactic Cap sample for a wide variety of future studies on AGN, and outline one such current project on the stacked emission from this sample and the connections with X-ray background synthesis models.

109.07 – New Techniques to Study Faint Ultra Hard X-ray Emission From SWIFT BAT Applied to the GOALS LIRG Sample

Michael Koss¹, Richard Mushotzky², Wayne H. Baumgartner³, Sylvain Veilleux², Jack Tueller³, Craig Markwardt³, Caitlin Casey¹, Neil Gehrels³

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Contributing teams: Swift BAT Team

We present the first analysis of the all-sky Swift BAT ultra hard X-ray (14-195 keV) data for a targeted list of objects. We find the BAT data can be studied at 3 times fainter limits than in previous blind detection catalogs based on prior knowledge of source positions and using smaller energy ranges for source detection. We determine the AGN fraction in 134 nearby ($z < 0.05$) luminous infrared galaxies (LIRGS) from the GOALS sample. We find that LIRGs have a higher detection frequency than galaxies matched in stellar mass and redshift at 14-195 keV and 24-35 keV. In agreement with work at other wavelengths, the AGN detection fraction increases strongly at high IR luminosity with half of high luminosity LIRGs (50%, 6/12, $\log L_{\text{IR}}/L_{\text{sun}} > 11.8$) detected. The BAT AGN classification shows 97% (37/38) agreement with Chandra and XMM AGN classification using hardness ratios or detection of a iron K-alpha line. This confirms our statistical analysis and supports the use of the Swift BAT all-sky survey to study fainter populations of any category of sources in the ultra hard X-ray band. BAT AGN in LIRGs tend to show higher column densities with 40pm9% showing 14-195 keV/2-10 keV hardness flux ratios suggestive of high or Compton-thick column densities ($\log N_{\text{H}} > 24$ cm⁻²), compared to only 12pm5% of non-LIRG BAT AGN. We also find that using specific energy ranges of the BAT detector can yield additional sources over total band detections with 24% (5/21) of detections in LIRGs at 24-35 keV not detected at 14-195 keV.

109.08 – The Combined Swift - INTEGRAL X-ray (SIX) Survey

Eugenio Bottacini¹, Marco Ajello², Jochen Greiner³

1. Stanford University, Stanford, CA, United States. 2. Space Science Laboratory, Berkeley, CA, United States. 3. Max-Planck-Institut für Extraterrestrische Physik, Garching, Bayern, Germany.

In the local universe ($z < 0.5$) Active Galactic Nuclei (AGN) are best surveyed at hard X-ray energies by Swift/BAT and INTEGRAL/IBIS. These two coded mask telescopes are selecting a sizable number of AGN and they are uncovering the obscured AGN population. However, the sensitivity of surveys performed with coded mask telescopes is limited by rather large statistical and systematic errors. I will show that Swift/BAT and INTEGRAL/IBIS are so close in design that their observations can be combined. This results in a new survey: the Swift-INTEGRAL X-ray (SIX) survey that is a factor of ~2 more sensitive than the surveys of both instruments alone. I investigate the nature of the SIX selected AGN and the implications for the study of their space density and evolution. I will address also the impact of the SIX survey on recent and forthcoming hard X-ray missions with focusing optics.

109.09 – The NuSTAR View of the Extragalactic Sky

Francesca M. Civano¹

1. Dartmouth College, Cambridge, MA, United States.

Contributing teams: NuStar Extragalactic Team

We present the first results from the NuSTAR extragalactic surveys: COSMOS and ECFDS. We will give a brief overview on the status of the two surveys after about 1 year of NuSTAR operation (area covered, number of detected sources and their properties).

110 – AGN/Galaxy Connections|AGN/Galaxy Connections|AGN/Galaxy Connections|AGN/Galaxy Connections

110.01 – The Dichotomous Evolution of AGN Host-galaxies

Andy D. Goulding¹, William R. Forman¹, Christine Jones¹, Ryan C. Hickox², Stephen S. Murray³

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Contributing teams: Members of XDEEP2, Members of AGES

Accreting supermassive black holes (BHs) in the form of active galactic nuclei (AGN) are capable of releasing substantial quantities of energy, often comparable to the binding energy of their host galaxies. Many theoretical and semi-analytical models require a close link between BH growth and host-galaxy evolution through mechanical and/or radiation driven feedback. Through careful comparison of AGN host galaxies at 0

110.02 – A Correlation Between Star Formation Rate and Average Black Hole Accretion Rate in Star-forming Galaxies

Chien-Ting J. Chen¹, Ryan C. Hickox¹, Stacey Alberts², Alexandra Pope²

1. Dartmouth College, Hanover, NH, United States. 2. University of Massachusetts, Amherst, MA, United States.

Contributing teams: Boötes Survey Collaboration

I will present the results of recent studies on the co-evolution of galaxies and the supermassive black holes (SMBHs) using Herschel far-infrared and Chandra X-ray observations in the Boötes and CDF-S survey regions. We find a strong correlation between galactic star formation rate and the average SMBH accretion rate in star-forming galaxies. Recent studies have shown that star formation and AGN accretion are only weakly correlated for individual AGN, but this may be due to the short variability timescale of AGN relative to star formation. Averaging over the full AGN population yields a strong connection between accretion and star formation, consistent with a simple picture in which the growth of SMBHs and their host galaxies are closely linked over galaxy evolution time scale.

110.03 – Observational Constraints on the Local Black Hole Occupation Fraction from X-ray Observations of Nearby (Formally) Inactive Galactic Nuclei

Elena Gallo¹, Brendan P. Miller¹

1. University of Michigan, Ann Arbor, MI, United States.

An issue of crucial relevance in understanding the connection between super-massive black holes and their host galaxies is the 'occupation fraction' of massive black holes in the present day universe. While the occupation fraction is expected to be close to 100% in high mass galaxies, predictions differ dramatically at the low mass end, with 'light' seeds (i.e. remnants from the first generation of stars) producing a greater nuclear occupation fraction compared to direct collapse models below a few billion solar masses. For an unbiased sample, the local active fraction represents a strong lower limit to the occupation fraction, and X-ray observations of nearby, formally inactive galaxies over a wide range in stellar masses can provide observational constraints to the very mechanism by which the first black holes formed. Adopting a Monte Carlo approach, we make use of the Chandra AMUSE-surveys to characterize simultaneously the black hole occupation fraction and the scaling of nuclear activity with host mass. Further, we discuss future prospects for improving the precision of these parameters as a function of sample size, as well as desired sensitivity and spatial resolution of future missions.

111 – AGN/QSO Jets

111.01 – Unifying Black Hole Jets Across the Mass Scale with Fermi and Swift

Rodrigo Nemmen¹, Markos Georganopoulos², Eileen T. Meyer³, Sylvain Guiriec¹, Neil Gehrels¹, Rita M. Sambruna⁴

1. NASA GSFC, Greenbelt, MD, United States. 2. University of Maryland Baltimore County, Baltimore, MD, United States. 3. Space Telescope Science Institute, Baltimore, MD, United States. 4. George Mason University, Fairfax, VA, United States.

In this talk, I will show that jets produced by active galactic nuclei (AGN) and gamma-ray bursts (GRBs) exhibit the same correlation between the kinetic power carried by accelerated particles and the gamma-ray luminosity, with AGN and GRBs lying at the low- and high-luminosity ends, respectively, of the correlation. This result implies that the efficiency of energy dissipation in jets produced in black hole systems is similar over 10 orders of magnitude in jet power, establishing a physical analogy between AGN and GRBs. (Nemmen et al. 2012, Science, arXiv:1212.3343)

111.02 – The Large Scale Jets of Powerful Quasars: Not as Fast, Not as Powerful, but Efficient Particle Accelerators

Markos Georganopoulos^{1, 2}, Eileen T. Meyer³

1. UMBC, Baltimore, MD, United States. 2. NASA/GSFC, Greenbelt, MD, United States. 3. STSCI, Baltimore, MD, United States.

Thirteen years ago Chandra discovered that the large scale jets of powerful quasars are copious X-ray emitters. The X-rays could be Inverse Compton scattering off CMB photons, provided that the jets remained highly relativistic (Lorentz factors 10-20) and carrying kinetic power comparable to the Eddington luminosity. Alternatively the X-ray could be synchrotron emission, relaxing the power and Lorentz factor requirements, but requiring leptons to be accelerated up to 100 TeV or more. This issue remains open today. In 2006, Georganopoulos et al. proposed a Gamma-ray diagnostic to distinguish between these two radically different cases. Here, we present the Fermi application of this diagnostic to the archetypical source 3C 273. A fast and powerful jet, and therefore an IC interpretation for the X-rays, is strongly disfavored by the data.

111.03 – Tracing the Origins of the Relativistic Jet Dichotomy – Accretion Mode, Spin, or Something More?

Eileen T. Meyer¹, Markos Georganopoulos², Giovanni Fossati³, Matthew L. Lister⁴

1. Space Telescope Science Institute, Baltimore, MD, United States. 2. University of Maryland, Baltimore County, Baltimore, MD, United States. 3. Rice University, Houston, TX, United States. 4. Purdue University, West Lafayette, IN, United States.

There are many unanswered, yet central questions regarding radio-loud AGN. Though several physical mechanisms have been put forward, from the 'spin paradigm' to magnetically arrested disks, we do not yet know how relativistic jets are produced, nor do we know what kinds of plasma are being accelerated or even for certain how long they remain relativistic. Differences in black hole spin, accretion mode, and/or the merger history and extragalactic environment have all been invoked to explain both the presence and differences among relativistic jets, yet we lack a unifying picture which explains this coherently. My recent work (Meyer et al., 2011) represents the start of a major shift in our understanding of radio-loud AGN unification, showing through multi-wavelength studies of large populations that there exists a dichotomy in jetted AGN, between 'strong' jets of higher kinetic powers and 'weak' jets, associated with efficient and inefficient accretion modes, respectively (Meyer et al., 2011, 2012) as first suggested by Ghisellini et al. (2009). This work has already brought many observations into agreement that were in conflict under the previous unification schemes and may open a way forward to finally solving some of the big questions about the physical origins of large-scale relativistic jets from supermassive black holes.

111.04 – What Did We Learn From Chandra, Xmm-Newton And Fermi-Lat About The High Energy Emission In Young Radio Sources?

Aneta Siemiginowska¹, Matteo Guainazzi², Martin Hardcastle³, Brandon C. Kelly⁴, Magda Kunert-Bajraszewska⁵, Giulia Migliori¹, Malgosia Sobolewska¹, Lukasz Stawarz⁶

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States. 2. ESA/XMM-Newton, Madrid, Spain. 3. University of Hertfordshire, Hertfordshire, United Kingdom. 4. UCSB, Santa Barbara, CA, United States. 5. Torun University, Torun, Poland. 6. JAXA, Tokyo, Japan.

Giga-Hertz Peaked Spectrum (GPS) and Compact Steep Spectrum (CSS) radio sources comprise a large population of compact objects with radio emission fully contained within the innermost regions of the host galaxy (< a few kpc). Spectral and kinematic age measurements indicate their young age (typically < thousands years and in some cases less a few hundred years). These sources provide the important insights to the initial phase of the jet formation, radio source growth, source evolution and the jet impact on the ISM in the very central regions of the host galaxy. We have obtained Chandra and XMM-Newton observations for a large sample of these sources over several observing cycles. Our most recent Chandra observations targeted Compact Symmetric Objects (CSO) associated with the nuclear regions of nearby galaxies. All these CSO have measured kinematic ages within 100-3000 year old. I will present the results of our ongoing observing program focusing on the high energy properties of these young sources.

112 – Astroparticles

112.01 – Energy Exchange Through Cross-Shock Potentials in Relativistic Plasma Shocks

Joseph Barchas¹, Matthew G. Baring¹

1. Rice University, Houston, TX, United States.

Diffusive shock acceleration as a method for generating high-energy cosmic rays and power-law high-energy photon populations in various sources has been well studied. Common techniques for modeling the acceleration mechanism include Monte Carlo transport and Particle-in-Cell simulations. The disparate scale between electron and ion gyroradii produces a cross-shock charge separation potential in the shock layer. Its effect in respective energization/de-energization of the electron/ion populations is not often isolated in acceleration simulations, and influences the ultimate efficiency of injection into the acceleration process. We use a Monte Carlo approach where test particles traverse a shock whose MHD structure is pre-defined by the usual Rankine-Hugoniot conditions. The cross-shock potential is obtained by solving Poisson's equation using the test particle spatial distributions. The field then modifies the motions of the charges in the shock layer. This interplay is iterated in a feedback loop until a self-consistent field profile is obtained. The changes obtained in electron/ion energy distributions and their effect on the subsequent acceleration to high energies are presented.

112.02 – Recent Evidence for Gamma-ray Line Emission from Fermi-LAT: WIMP or Artifact?

Meng Su^{1, 2}, Douglas P. Finkbeiner²

1. MIT, Cambridge, MA, United States. 2. Harvard University, Cambridge, MA, United States.

The recent claims of a gamma-ray line in the Galactic center at 130 GeV have generated excitement, not least because it could be a signal of dark matter annihilation. I will summarize the current state of the observations of the Galactic center, clusters, and unassociated halo objects. I will also speculate about models of particle dark matter that could explain the data, and possible systematic of the Fermi-LAT instrument that might contaminate the line detection.

112.03 – Cosmic Ray Electrons, Positrons and the Synchrotron emission of the Galaxy: consistent analysis and implications

Giuseppe Di Bernardo^{1, 6}, Carmelo Evoli⁴, Daniele Gaggero³, Dario Grasso^{2, 7, 8}, Luca Maccione^{5, 8}

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The study of the physics of Galactic cosmic rays is one of the most active research areas at present. Sensible advances in the field have come in connection to the wealth of high-accuracy data recently collected by several new instruments, with further progresses expected in the upcoming future. In our recent work (arXiv:1210.4546, accepted for publication in JCAP) a multichannel analysis of cosmic ray electron and positron spectra and of the diffuse synchrotron emission of the Galaxy has been performed by using the publicly available DRAGON code. In light of the recently published data from the Fermi-LAT and PAMELA collaborations, we show that above 4 GeV the electron source spectrum is compatible with a power-law of index ~ 2.5 , the so-called standard scenario, in which cosmic ray electrons are produced by galactic supernova remnants. Below the same energy the electron primary spectrum instead must be significantly suppressed so that the total spectrum will turn out to be dominated by secondary particles. The positron spectrum measured below few GeV is therefore consistently reproduced only within low re-acceleration models. Furthermore, one of the primary goals of our analysis is to constrain, by reproducing the radio data, the scale-height z_t of the cosmic ray distribution; we show that a thin galactic halo ($z_t < 2$ kpc) is excluded. If published at ICRC time, forthcoming AMS-02 results will be also discussed in this context.

113 – Black Holes in Globular Clusters

113.01 – A Deep X-ray Search for the Putative IMBH in Omega Centauri

Daryl Haggard¹, Adrienne Cool², Craig O. Heinke³, Haldan N. Cohn⁴, Phyllis M. Lugger⁴, Roeland P. Van Der Marel⁵, Jay Anderson⁵

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Omega Centauri, the Milky Way's most massive and enigmatic old stellar cluster, offers a treasure trove of astronomical discovery and controversy, including debate about the existence of an intermediate mass black hole (IMBH) buried in the cluster's core. We report preliminary results of deep (~290 ksec) Chandra ACIS-I imaging of Omega Cen, which reveals no X-ray source at the cluster center reported by Anderson and van der Marel (2010), or at any other proposed center for the cluster. We discuss the significance of this new X-ray limit for the possible presence of an IMBH in Omega Cen. We also briefly describe our multiwavelength imaging and spectroscopic campaigns, which probe Omega Cen's binary populations, and the light they shed on the cluster's dynamical history.

113.02 – Striking Variability from the Globular Cluster Black Hole XMMU 122939.7+075333

Tana Joseph^{1, 3}, Thomas J. Maccarone², Ralph P. Kraft³, Gregory R. Sivakoff⁴

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Contributing teams: Chandra LP Team

XMMU 122939.7+075333 was the first black hole system discovered in a globular cluster. This source is situated in a spectroscopically confirmed globular cluster, RZ2109, of NGC 4472, a massive elliptical galaxy falling into the Virgo cluster. In this talk I will present the most recent X-ray data for this source. The source flux is found to be varying on timescales of hours and still faint compared to previous observations. Spectroscopic analysis has revealed suggestive evidence of emission from highly ionized oxygen. I will discuss how these data, along with previous multiwavelength studies of the source, constrain the nature of XMMU 122939.7+075333.

113.03 – Spatially Resolved Spectroscopy of the Globular Cluster RZ2109 and the Nature of its Black Hole

Mark Peacock¹, Stephen E. Zepf¹, Arunav Kundu², Thomas J. Maccarone³, Katherine L. Rhode⁴, John J. Salzer⁴, Christopher Z. Waters⁵, Robin Ciardullo⁶, Caryl Gronwall⁶, Daniel Stern⁷

1. Michigan State University, East Lansing, MI, United States. 2. Eureka Scientific, Inc., Oakland, CA, United States. 3. University of Southampton, Southampton, United Kingdom. 4. Indiana University, Bloomington, IN, United States. 5. University of Hawaii at Manoa, Honolulu, HI, United States. 6. The Pennsylvania State University, University Park, PA, United States. 7. JPL, Caltech, Pasadena, CA, United States.

We present optical HST/STIS spectroscopy of RZ2109, a globular cluster in the elliptical galaxy NGC4472. This cluster is notable for hosting an ultraluminous X-ray source and is known to have associated strong and broad [OIII] emission. Our observations of this cluster spatially resolve its [OIII] emission and are used to demonstrate that the nebula is similar in scale to the cluster itself, with a half light radius of at least a few parsecs. The properties of this nebula provide important constraints on the source of the emission observed from this cluster. We show that the large spatial scale of the nebula is inconsistent with models that invoke an intermediate mass black hole origin. It is also inconsistent with other models that propose the ionization of ejecta from a nova in the cluster. We show that the nebular emission could be produced via the photoionization of a strong wind driven from a stellar mass black hole that is accreting at roughly its Eddington rate.

113.04 – Radio Continuum Observations of Black Holes and Neutron Stars in Galactic Globular Clusters

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We present new VLA radio continuum observations of several Galactic globular clusters, including the enigmatic object Terzan 5. The unprecedented depth of these data has allowed us to identify candidate black holes and search for faint pulsars missed in traditional timing observations.

114 – Blazars and BL Lacs

114.01 – Compton Dominance and the Blazar Sequence

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Does the 'blazar sequence' exist, or is it a result of a selection effect, due to the difficulty in measuring the redshifts of blazars with both high synchrotron peak frequencies ($> \sim 10^{15}$ Hz) and luminosities ($> \sim 10^{46}$ erg s^{-1})? We explore this question with a sample of blazars from the Second Catalog of Active Galactic Nuclei (AGN) from the Fermi Large Area Telescope (LAT). The Compton dominance, the ratio of the peak of the Compton to the synchrotron peak luminosities, is essentially a redshift-independent quantity, and thus crucial to answering this question. We find that a correlation exists between Compton dominance and the peak frequency of the synchrotron component for all blazars in the sample, including ones with unknown redshift. We then construct a simple model to explain the blazar properties in our sample, where the difference between sources is due to only the magnetic field of the blazar jet emitting region, the external radiation field energy density, and the jet angle to the line of sight, with the magnetic field strength and external energy density being correlated. This model can reproduce the trends of the blazars in the sample, and predicts blazars may be discovered in the future with high synchrotron peak frequencies and luminosities. At the same time the simple model reproduces the lack of high-synchrotron peaked blazars with high Compton dominances ($> \sim 1$).

114.02 – Insight into the Blazar Emission Environment from X-ray Absorption

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Collecting experimental insight into the relativistic particle populations and emission mechanisms at work within TeV-emitting blazar jets is complicated by the point-like, beamed nature of the broadband emission. Detection of molecular carbon monoxide (CO) in TeV emitting blazars, however, might imply the existence of neutral hydrogen gas, a connection often found in photo-dissociated region models and numerical simulations. Gas within a blazar could provide a target photon field, either through thermal emission or reflection, for Compton up-scattering of photons to TeV energies by relativistic particles. We investigate the possible existence of gas within the three TeV emitting blazars RGB J0710+591, W Comae and 1ES1959+650 by combining a spectral analysis of soft X-rays with measurements or upper limits on molecular CO line luminosity. Evidence for X-ray absorption by additional gas beyond that measured within the Milky Way is searched for in Swift X-ray Telescope (XRT) data between 0.3 and 10 keV and can be misinterpreted as an intrinsically curved X-ray spectrum. No evidence for intrinsically curved spectra is found for any of the three blazars if additional absorption is considered. Moreover, the results from X-ray data on additional absorption agree with the measurements of molecular CO line luminosity for the three blazars explored here.

114.03 – Highlights of the VERITAS Blazar Observation Program

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Contributing teams: VERITAS Collaboration

VERITAS is an array of four 12m imaging atmospheric Cherenkov telescopes, sensitive to gamma-rays with energies ~ 100 GeV to ~ 50 TeV. Studies of blazars comprise roughly 40% of all VERITAS observations, and include monitoring of known very high energy (VHE) gamma-ray sources and efforts to detect new blazars in the VHE regime. I will present an overview of the VERITAS blazar observation program, and highlight its key results from the past ~ 18 months. I will also discuss the impact of the newly-upgraded VERITAS cameras on our blazar studies, including the first VERITAS detections of some soft-spectrum blazars in late 2012.

114.04 – Swift Monitoring of 3C 454.3 During a Prolonged Low Gamma-ray State

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The blazar 3C 454.3 is a well-known, extremely variable flat-spectrum radio quasar which exhibited the most intense gamma-ray flares detected up to now. Thanks to the Swift innovative and unique pointing strategy, it has been possible to monitor this source in the UV and X-ray energy bands on time-scales comparable to the ground-based optical and radio ones. The long-term multi-wavelength light-curves allowed us to obtain detailed information on time-lags between the flux emission in different energy bands, to investigate the properties of the jet during the most intense gamma-ray flares, and to study the radiation mechanisms responsible for the emission at different frequencies. In particular we found that, during extreme gamma-ray flares, the harder-when-brighter correlation noted during low and intermediate gamma-ray states does not hold anymore, leading to an achromatic increase of the X-ray flux, interpreted in terms of a balance of the synchrotron self-Compton contribution with respect to the external Compton on the disc radiation. We present our new results of an on-going Swift monitoring of 3C 454.3 during a prolonged low gamma-ray state. Our monitoring allows us to extend our study of a poorly sampled region of the X-ray spectral index vs. flux diagram, where a clear correlation between the two quantities (if any) is unclear, and improve our current understanding of this spectral trend in terms of the relative contribution of different emission components.

114.05 – A Systematic Study of Spectral Breaks in Gamma-Ray Flares of Blazars

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The gamma-ray energy spectra of luminous blazars often show significant spectral breaks. Despite several dedicated studies, the physical cause of these features is not well-understood. In this work, we investigate the relationships between various parameters of gamma-ray blazar flares in order to further our understanding of the mechanism that causes the spectral breaks. As a follow-up to Nalewajko (2012), who presented a sample of the brightest blazar flares detected by the Fermi Large Area Telescope in its first four years of operation, we systematically study the flare spectra and identify spectral breaks. We examine the relationships between the spectral break energy, the photon index change, and other flare properties such as the peak flux and the duration. We then use the results of this analysis to discuss potential physical mechanisms that might cause the gamma-ray spectral breaks in blazars.

114.06 – Localizing the Brightest Blazar Gamma-ray Flare Ever

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The location of the GeV-flaring zone in bright Fermi blazars is an important topic of debate: is the GeV emitting region located inside the sub-pc broad line region (BLR) or farther out in the pc-scale molecular torus (MT)? We recently presented a diagnostic that relies on the energy dependence of the flare decay time. Here we show results of our method, applied to the November 2010 flare of 3C 454.3, the brightest recorded blazar flare. We split the flare into two energy bands ($E < 1$ GeV and $E > 1$ GeV) and fit an exponential rise and decay to each flare component. As we will show, the resulting fit decay times $T_{f, HE}$ and $T_{f, LE}$ indicate that the flaring site is located within 5 pc from the central engine. We discuss analysis of the 3C 454.3 flare, the implications of the fit for the location of the GeV emitting zone, and future plans to apply this method to a wider survey of objects.

114.07 – Two Swift Public Monitoring Programs on Fermi Blazars and Fermi Unassociated Sources

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Two Swift programs are providing valuable, easily accessible, and automatically processed data to the community in near real-time. The first program is a long term monitoring program on Fermi blazars, as well as many other variable high energy sources, enabling multiwavelength campaigns, in-depth studies of flaring, and studies of long-term behavior. In the second program, we are using Swift to search for X-ray and UV/optical counterparts of unassociated Fermi gamma-ray sources, which are likely to be dominated by new gamma-ray blazars and may also harbor pulsars, as well as new exciting source classes. This Swift program includes pointed observations, with typical durations of ~ 4 ks, of Fermi catalog sources with no currently known source association at other wavelengths. For each of the Fermi-LAT localization ellipses, Swift-XRT obtains accurate source positions (~ 5 arcsec) of any detected X-ray sources, enabling new blazar identification observations and pulsation searches at both radio and gamma-ray wavelengths. Together with follow-up at other wavelengths, this study aims to reveal the nature of these unassociated and unidentified gamma-ray sources. Some results from these programs will be presented, along with information about the public availability of the processed data in near real-time.

114.08 – High-Energy Polarization Signatures of Leptonic and Hadronic Models for Blazars

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The advent of new X-ray polarimeters as well as the potential of Fermi to measure gamma-ray polarization up to 200 MeV opens a new window of opportunity to diagnose the structure and composition of relativistic jets in blazars, the dominant radiation mechanisms, and the location of the gamma-ray emission zones. We have developed a versatile code to evaluate the X-ray and gamma-ray polarization from synchrotron and synchrotron self-Compton emission for arbitrary particle distributions in blazar jets. This code is applied to make predictions for the degree of polarization at X-ray and soft gamma-ray energies for parameters resulting from existing leptonic and hadronic single-zone model fits to the SEDs of a number of Fermi detected blazars.

114.10 – Multiwavelength Probes of Relativistic Shock Environs in Blazar Jets

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Diffusive shock acceleration (DSA) at relativistic shocks is likely to be an important acceleration mechanism in various astrophysical jet sources, including radio-loud AGN. 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 diagnostic potential was not possible prior to Fermi launch, when gamma-ray information was dominated by the highly-absorbed TeV band. 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 blazars. The spectral index of the nonthermal particle distributions resulting from Monte Carlo simulations of DSA, and the fraction of thermal particles accelerated to non-thermal energies, depend sensitively on the particles' mean free path scale, and also on the shock magnetic field obliquity. We investigate self-consistently the radiative (synchrotron + Compton) signatures of the resulting thermal and nonthermal particle distributions. Important constraints on the frequency of particle scattering and the level of field turbulence are identified for blazars such as Mrk 501 and the BL Lac object AO 0235+164. The possible interpretation that turbulence levels decline with remoteness from the shock, and a significant role for non-gyroresonant diffusion, are discussed.

114.11 – Time Dependent Leptonic Modeling of Blazar Jets

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We present simulations for a time dependent leptonic model to reproduce the features found in spectral energy distributions of flat spectrum radio quasars (FSRQ's) and BL Lac objects. Blazars are known for their absence of emission lines and relatively featureless continuum radiation emission. Conversely, FSRQ's contain prominent emission lines as well as contributions from external radiation fields surrounding a supermassive black hole (SMBH). We simulate time evolved SEDs from a series of different input parameters to understand the effects these input parameters have on the output. Our model is able to produce continuum radiation from synchrotron and synchrotron self-comptonization (SSC) from a time evolved distribution of electrons moving relativistically along the axis of the blazar jet. The model also considers contributions from external radiation fields and their subsequent scattering to higher energies due to external Compton processes. The results of our simulations agree well with the expected normalization constants for the overall flux of the spectral energy distributions from the input parameters involved.

115 – Charge Exchange

115.01 – The Search for the X-ray Bow-shock in the Chandra ACIS-S Sample of Comets

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We present results of our study of the X-ray image morphology and the search for the X-ray bow shock for a sample of comets observed with the Chandra X-ray observatory and ACIS spectrometer. We have selected 5 comets from the Chandra sample with good signal-to-noise. The surveyed comets are: C/1999 S4 (LINEAR), C/1999 T1 (McNaught-Hartley), 153P/2002 (Ikeya-Zhang), 2P/2003 (Encke), and C/2008 8P (Tuttle). Comets generally show a large and diffuse crescent-shaped image morphology in the X-ray and their low surface brightness makes detailed analysis difficult. Exposure corrected images were created in several energy bands in the 250 to 2000 eV range and searched for changes as a function of distance and azimuthal angle from the comet toward the sun in a manner similar to Wegmann & Dennerl 2005. Initial results for Encke, which is optically thin, shows no evidence for an X-ray bow shock in differential image profiles. LINEAR S4 shows a gradual transition between ~ 0.9 - 1.2×10^5 km from the nucleus in differential images that we interpret as evidence for the bow shock, but further analysis is underway. Results for the other comets in the sample will also be presented. This research was supported by Chandra archival grant CXO-13100089.

115.02 – X-rays via Charge Exchange from the Solar System and Beyond

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Charge exchange (CX) involving ions in the solar wind and beyond can create X-ray emission lines indistinguishable at moderate resolution from those created in collisional or photoionized plasmas. The prime distinguishing characteristic is in the distinctly different line ratios generated by the CX process, which can only be detected at high ($R > 300$) resolutions. A complete astrophysical model of the process would require a vast number of atomic calculations; we describe here an approximate approach that will allow astronomers to evaluate the likely contribution of CX to an observed spectrum. The method relies upon new extremely detailed atomic structure calculations used to determine the emission lines. Simulated spectra based on observed solar wind CX data are shown for both current and near-term missions such as Astro-H.

115.03 – Characterization of Solar Wind Charge Exchange with Suzaku

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The Solar Wind Charge Exchange (SWCX) is one of the major contributors to the X-ray emission in the [0.3-0.9] keV band and possibly the strongest local component. SWCX is characterized by emission lines, however its intensity shows both temporal and spatial variations as it depends on the solar activity and on the relative positioning between the observer, the Sun, and the line of sight. SWCX is due to the interaction of the solar wind with neutrals and it is the superposition of two components, magnetosheath and heliospheric. The first one is varying on a very short time scale of hours to days, due to the interaction of solar wind with neutrals in our atmosphere, and can have very strong emission bursts. The second one is on average the dominant component. It varies more smoothly on a time scale of several days to months, due to the diffusion time of the wind through the solar system. An annual modulation due to distributions of interstellar neutrals (H and He) passing through the solar system is also present. The heliospheric emission is the focus of a Suzaku key project. Nearby (~ 100 pc) high column density clouds absorb the X-ray contribution from distant sources and the leftover signal has local origin (and is expected to be dominated by SWCX). The project consists of a three year monitoring campaign of four high density clouds. Besides the high density the targets have been selected for their position in the sky, in order to maximize the latitude and longitude range and to model how SWCX depends on the distribution of neutrals. Three of the targets will be therefore observed once a year in order to characterize how SWCX depends on the solar wind (long term dependence). The fourth target will be observed twice a year, this allows to study also the annual modulation of SWCX. The targets shows a significant variation between the two Suzaku's observing windows because the pointing partially goes through the He focusing cone in one window, but is far from it in the other. Here we present the preliminary results on the data taken during the first year of the project.

116 – Clusters & Surveys

116.01 – XMM-Newton Observation of the IGR J17448-3232 Field

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We present our analysis of a 43-ks XMM-Newton observation of the IGR J17448-3232 field. The main features of this field are a nearly circular extended source of $\sim 4'$ radius encompassing a bright point source at its edge. Despite the proximity of this field with the galactic center ($l=356.8^\circ$, $b=-1.8^\circ$), we find that both components are of extragalactic origin. We propose that the extended source is a nearby galaxy cluster at redshift ~ 0.05 and the point source a blazar candidate, in agreement with Curan et al. 2011.

116.02 – A Supercluster at Redshift 1.71 in the Lockman Hole

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We previously reported evidence for an X-ray selected galaxy cluster in the Lockman Hole at $z = 1.75$ based on 1 spectroscopic and 7 photometric redshifts. We confirm the previous redshift and present concordant spectroscopic redshifts for an additional 8 galaxies and newly calibrated photometric redshifts for a further 76 galaxies. Scrutiny of the galaxy distribution in redshift and plane of the sky shows that there are 3 structures in a line connected by a filament. The original X-ray object lies between two galaxy concentrations, one of which is likely a X-ray source. Initial analysis of the galaxy color-magnitude diagram shows the quiescent galaxies formed at $z \sim 3$.

116.03 – Probing the Outskirts of Galaxy Clusters: Progress and Pitfalls

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Over the past several years, a number of studies have traced the hot intracluster medium (ICM) to the virial radius and beyond in a number of galaxy clusters. Many of these observations have been performed with the Suzaku X-ray Observatory, and the results have begun to clarify the ICM conditions at the edge of clusters, helping to constrain models of cluster growth and structure. We are currently embarked on a program to observe a large sample of relaxed clusters with Suzaku, leveraging complementary data from XMM and Chandra. Our analysis, presented in a companion poster, indicates that the ICM is not in hydrostatic equilibrium in the cluster outskirts, where we see clear azimuthal variations in temperature and surface brightness. However, a host of systematic issues can bedevil these challenging low-surface-brightness observations, including unresolved point sources, diffuse background fluctuations, scattered light, and instrument calibration uncertainties. We explore these issues in detail for our observing program and other studies using Suzaku, and compare these limitations to other methods of probing the final frontier in clusters.

116.04 – The Outskirts of Galaxy Clusters: To r_{200} and Beyond with Suzaku, XMM-Newton and Chandra

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Galaxy clusters are the largest gravitationally bound structures in the universe and thus provide the best opportunity to study cosmology at work. Their outskirts, regions close to the virial radius, have not been well studied and could aid in our understanding of cluster growth, structure and mass. We show results from a program to constrain the properties of the outer intra-cluster medium in a sample of galaxy clusters, making use the strengths of the three complementary X-ray observatories: Suzaku which has a low and stable background, XMM-Newton which has a very high sensitivity, and Chandra which provides good spatial resolution. The sample comprises eleven mostly relaxed clusters at $z \sim 0.1-0.2$ with full azimuthal coverage to beyond r_{200} . Here we report results obtained from a few of the clusters starting with Abell 773. We are able to measure diffuse X-ray emission well beyond r_{200} . Our results suggest that the ICM is not in hydrostatic equilibrium in the outskirts of this cluster: we detect clear azimuthal variations in temperature and surface brightness. We also present the density, entropy and baryonic function profiles for each of these clusters.

116.05 – Investigating the Properties of a WHIM Filament in the Shapley Supercluster

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In a recent Suzaku observation searching for an intercluster filament between A3556 and A3558 in the Shapley Supercluster we found evidence of a significant Ne IX emission and a stronger than usual “power law” emission, which is generally associated with unresolved point sources. As part of the project we also observed two control targets, one less than 2 deg away, but they did not show any sign of this strong component, suggesting that it could be originated by a filament. Suzaku, however, does not have a good angular resolution, thus making it almost impossible to identify significant point sources. This is a strong limit to our ability to understand and characterize the origin of the excess emission and therefore the properties of any filament (if present). We therefore performed a short Chandra ACIS-S observation (10 ks) in the inner region of the Suzaku field of view in order to identify and characterize more than half of the expected point source flux and allow an understanding of the origin of the excess emission, necessary to characterize any possible WHIM filament in the Suzaku

observation. The Chandra observation, in fact, is intended to characterize the number and flux of point sources in the filament region; to determine if the excess flux is due to the point sources and if they have a higher density than average; in this case to investigate if it is due to an additional class of sources (also responsible for the Ne IX line) and if it can be associated with the filament; if the excess emission is due to diffuse filament emission, understand the properties of the emitting plasma; investigate the origin and nature of the strong Ne IX emission. Here we present the preliminary results of the analysis of the combined Suzaku and Chandra observations.

116.06 – CLoGS - The Complete Local-Volume Groups Survey

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The current lack of a statistically representative sample of nearby galaxy groups observed in the X-ray is a serious hindrance to studies of galaxy evolution, structure formation, and feedback processes. To address this problem we have defined an optically selected, statistically complete sample of 53 nearby galaxy groups, screened to exclude systems that are uncollapsed or embedded in larger structures. We have X-ray observations of about 2/3 of the sample, including all of the richer half, and have completed low-frequency observations of the full sample with the Giant Metrewave Radio Telescope (GMRT). Optical selection avoids the known bias toward centrally concentrated cool-core systems in X-ray samples chosen from the ROSAT All-Sky Survey, while X-ray follow-up will allow us to confirm that the groups are truly virialized. The combination of X-ray, optical, and radio data for these nearby systems means that as well as determining the physical properties of the local group population for the first time, we will be able to study the impact of AGN on the intra-group medium and member galaxies. In this poster, we present details of our selection and first results from new Chandra, XMM-Newton, and GMRT observations of our groups, showing the range of group morphologies and properties in the sample.

116.07 – The Infall of the MCG+10+24-117 Into the NGC 6338 Galaxy Cluster

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We present preliminary results of an X-ray analysis of 47 ksec with the Chandra satellite aimed at the cluster NGC 6338. The hot ISM density profile of MCG+10+24-117 shows a sharp edge at about 6 kpc from its center in the direction of NGC 6338. The discontinuity is consistent with a cold front, where gradient factors of about 1.7 both in density and in gas temperature are measured with no significant radial pressure gradient. We argue that the front is due to an ram pressure stripping of the galaxy gas, caused by its subsonic motion through the surrounding intracluster medium.

116.09 – Dulling Occam's Razor: ICM Enrichment, the Elliptical Galaxy IMF, and the Diversity of Star Formation

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Stars born in galaxy cluster potential wells must be responsible for the high level of enrichment measured in the intracluster medium (ICM); however, there is increasing tension between this truism and the parsimonious assumption that the stars in the generally old population studied optically in cluster galaxies emerged from the same formation sites at the same epochs. We construct a phenomenological cluster model to demonstrate that ICM enrichment is underestimated by a factor >2 for standard assumptions, and quantify the adjustments to the star formation efficiency and initial mass function (IMF), and SNIa production efficiency, required to rectify this while being consistent with the observed ICM abundance pattern. Given recent evidence of a steep IMF in elliptical galaxies that conflicts with the nucleosynthetic requirements of the ICM, we are led to conclude that the stellar population responsible for enriching the ICM is currently hidden and offer some suggestions as to where. This study proves that the star formation cannot be invariant in space and time.

116.10 – Characterization of ICM Temperature Distributions of 62 Galaxy Clusters with XMM-Newton

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We measure the intracluster medium temperature distributions for 62 galaxy clusters in the HIFLUGCS, an X-ray flux-limited sample, with available X-ray data from XMM-Newton. We search for correlations between the width of the temperature distributions and other cluster properties, including median cluster temperature, luminosity, size, presence of a cool core, AGN activity, and dynamical state. We use a Markov Chain Monte Carlo analysis which models the ICM as a collection of X-ray emitting smoothed particles of plasma. Each smoothed particle is given its own set of parameters, including temperature, spatial position, redshift, size, and emission measure. This allows us to measure the width of the temperature distribution (σ_{kT}), median temperature (kT_{med}), and total emission measure of each cluster. Of all 62 clusters, none have a temperature width consistent with isothermality. Counterintuitively, we also find that the temperature distribution widths of disturbed, non-cool-core, and AGN-free clusters tend to be wider than in other clusters. A linear fit to $\sigma_{kT} \sim kT_{med} + 0.82$, with an estimated intrinsic scatter of 0.61 keV, demonstrating a large range in ICM thermal histories.

116.11 – A Deep XMM-Newton Look at the Most Powerful Radio Halo Merging Galaxy Cluster MACSJ0717.5+3745

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We present the latest results from the 150 ks XMM-Newton observation of the most powerful radio halo galaxy cluster MACSJ0717.5+3745 ($z=0.55$). This spectacular merging galaxy cluster reveals important clues into the connection between the population of non-thermal synchrotron emitting particles and the diffuse, X-ray emitting, thermal gas. Utilizing XMM-Newton's excellent collecting area and spatial-resolution, we focus upon the morphology of the thermal properties of the diffuse gas and discuss the presence of a potentially non-thermal X-ray spectral component.

116.12 – Metallicity Distributions of the Innermost 100 kpc of Galaxy Clusters

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It is known that the Fe abundance profiles of cool core galaxy clusters are generally rising toward their central regions. However, in some cool core clusters, the abundance profiles appear to be dropping closest to the center ($r < 50\text{--}100$ kpc). How much the drops are due to multi-temperature bias or real decrements in abundance is not yet well understood. We conduct a statistical study of abundance determination in the central regions of galaxy clusters utilizing Chandra archival data. Our sample is comprised of low-redshift clusters ($z < 0.09$), which allows us to investigate detailed abundance distributions with high spatial resolution within the central 100 kpc. We present initial results on a sub-sample of about 10 clusters (including both cool core and non-cool core) of our sample, with evidence of abundance drops in at least half of the clusters. We discuss possible modeling biases as well as correlations between abundance patterns and intracluster medium properties of these clusters.

116.13 – Cosmic Ray Dynamics Inside the Cygnus A Radio-X-ray Cavity

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Our recent numerical computations describe the gasdynamical evolution inside the Cygnus A radio-X-ray cavity which is formed in the surrounding hot cluster atmosphere by jets from a cluster-centered black hole. Relativistic cosmic rays (CRs) and magnetic fields in the cavities originate in kpc-sized hotspot regions behind powerful reverse shocks where jets first confront high pressure cluster gas. CRs and field flow away from the hotspot in a wind, then are diverted to flow back along the cavity boundary toward the central black hole. The spatial distribution of computed CR ages agrees with well-ordered observed radio synchrotron ages only if hydrodynamic instabilities inside the cavity are damped – this is accomplished with a small viscosity of unknown origin. Computed radio synchrotron emission is dramatically limb-brightened in excellent agreement with Cygnus A observations. When viewed in projection, edge-brightened synchrotron emission from the cavities creates a roughly uniform radio surface brightness, analogous to the nearly uniform gamma-ray surface brightness in the Fermi bubbles. The brightest nonthermal radio-synchrotron and SSC X-ray emission in Cygnus A occurs not at the hotspot but about 1.5 kpc ahead where the hotspot wind compresses against dense cluster gas. Such offsets between the hotspot and peak radio brightness are commonly observed. Dynamical advection from the hotspot into the radio lobes establishes a relationship between CRs and fields observed in these two regions.

116.14 – Role of Magnetic Field Strength and Numerical Resolution in Simulations of the Heat-flux Driven Buoyancy Instability

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The role played by magnetic fields in the intracluster medium (ICM) of galaxy clusters is complex. The weakly collisional nature of the ICM leads to thermal conduction that is channeled along field lines. This anisotropic heat conduction profoundly changes the stability of the ICM atmosphere, with convective stabilities being driven by temperature gradients of either sign. We employ the Athena magnetohydrodynamic code to investigate the local non-linear behavior of the heat-flux driven buoyancy instability (HBI), relevant in the cores of cooling-core clusters where the temperature increases with radius. We study a grid of 2-d simulations that span a large range of initial magnetic field strengths and numerical resolutions. For very weak initial fields, we recover the previously known result that the HBI wraps the field in the horizontal direction thereby shutting off the heat flux. However, we find that simulations which begin with intermediate initial field strengths have a qualitatively different behavior, forming HBI-stable filaments that resist field-line wrapping and enable sustained vertical conductive heat flux at a level of 10-25% of the Spitzer value. We explain the presence and persistence of these filaments in terms of the linear stability of the HBI and the total energetics of the plasma. A complimentary 3-d simulation of high resolution confirms the presence of sustained filaments and shows they can be formed in the ideal MHD regime, even without anisotropic viscosity, previously thought to be necessary. While astrophysical conclusions regarding the role of conduction in cooling cores require detailed global models and a better understanding of conduction in the ICM, our local study proves that systems dominated by HBI do not necessarily quench the conductive heat flux.

116.15 – Searching For Dark Matter Decay Annihilation in the Stacked X-ray Spectra of Galaxy Clusters

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Galaxy clusters are the largest cosmological reservoirs of dark matter, making them unique probes for the search of dark matter annihilation signal due to the existence of large dark matter haloes. We searched for spectral features of sterile neutrino annihilation in XMM-Newton X-rays observations of seventy brightest nearby galaxy clusters determined by their expected dark matter flux. I will present the constraints on the mass and mixing angle of the dark matter sterile neutrinos we obtained from this stacked analysis of the X-ray spectra in the emitter (blue-shifted) frame.

116.18 – First Results from the Chandra COSMOS Legacy Survey: A New Window on the High-z Universe

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Contributing teams: Chandra COSMOS Legacy Survey Team

The 2 sq.deg. COSMOS area is the only large field for which a complete, deep, pan-chromatic data set exists, thanks to an outstanding survey effort over nearly a decade. Now, the COSMOS survey is undergoing major extensions, via the newly approved Chandra COSMOS Legacy Survey ('COSMOS-Legacy') and other programs. COSMOS-Legacy is the second largest Chandra proposal ever approved. COSMOS-Legacy will uniformly cover the 1.7 sq.deg. COSMOS/HST field with 2.8 Ms of Chandra ACIS-I imaging at ~ 160 ksec depth, expanding the deep C-COSMOS area by a factor of ~ 3 at $\sim 3e-16$ erg/cm²/s (1.45 vs 0.44 deg²). A total area of 2.2 deg² will be covered. The first ten 50ks tiles (as of Jan 2013), out of 56 tiles, have been observed. At least other twenty are scheduled by the end of March 2013. At the same time NuSTAR is observing COSMOS for 3 Msec in the harder (5-80 keV) band to 5e-14 cgs (10-30 keV) complementing the Chandra observations. The area and depth of COSMOS Legacy are designed to detect $\sim 40 z > 4$, and $\sim 4 z > 5$ Large Scale Structures on > 15 arcmin scales. These proto-structures have proven to connect luminous AGN and sub-mm galaxies in the early Universe. Over 200 $z > 3$ X-ray AGN (below and above $L_x = 10^{44}$) are expected, many of which should lie in these structures. To fully characterize the high-z X-ray sources in the structures, COSMOS Legacy is supported by spectroscopic follow-up observations (DEIMOS and MOSFIRE at Keck, KMOS at the VLT, FMOS at Subaru). New deep imaging surveys with Spitzer and JVLA are underway to define the properties of the galaxies in the structures up to $z \sim 7$. Extremely deep, $r_{AB} = 28.2$, optical imaging in grizY are planned with the new HyperSuprimeCam on Subaru as well.

117 – Data Analysis and Modeling Techniques

117.01 – X-ray Reflected Spectra from Accretion Disk Models: A Complete Grid of Ionized Reflection Calculations

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We present a new and complete library of synthetic spectra to model the reprocessed and reflected X-ray radiation from illuminated accretion disks, using an updated version of our code XILLVER. Several improvements have been implemented to both the routines and the atomic data, allowing the production a large grid of reflection models covering a wide range of parameters. Each model is characterized by the photon index Γ of the illuminating radiation (assumed to be a power-law), the ionization parameter ξ at the surface of the disk (i.e., the ratio of the X-ray flux over the gas density), and the iron abundance A_{Fe} with respect to the solar value. The ranges of the parameters covered are: $1.2 \leq \Gamma \leq 3.4$, $1 \leq \xi \leq 10^4$, and $0.5 \leq A_{\text{Fe}} \leq 10$. This choice is motivated to represent the physical conditions typically observed in most active galactic nuclei, as well as in some galactic black holes. This library is particularly intended to model reflection from accreting sources where the thermal disk emission is small compared to the incident power-law spectrum. A total of 720 reflection spectra are provided in a single FITS file suitable for the analysis of X-ray observations via the atable model in XSPEC. A detailed comparison with previous models highlights the improvements achieved in the present calculations, and their implications on the analysis of X-ray spectra is discussed.

117.02 – Two-temperature and Model-Independent Differential Emission Measure Distributions: The Emperor's New Clothes?

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Ill conditioning of both X-ray lines and continua present a well-known problem, which generally renders it impossible to formally invert observed X-ray spectra into meaningful source distributions. This problem is often addressed by the forward approach of parametrizing the source distribution, and varying the parameters until a best fit is achieved. However, this technique trades the ill conditioning of inversions for ambiguities in the parametrized sources, because a qualitatively different parametrized form might also yield an acceptable fit to the data. The severity of this ambiguity problem is explored in a general way, and it may force the abandonment of the concept of model-independent differential emission-measure distributions, in favor of intentionally fitting the spectrum within the context of some particular source model, in order to address some specific question. In particular, two-component plasma fits may only be physically meaningful in contexts where the plasma is already assumed to be two components— the X-ray spectrum will often not be able to establish that structure as an objective fact, forcing researchers to choose more carefully what they wish to learn from the spectrum.

117.03 – Modeling the Background in the HETGS Observations of the Galactic Center

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Last year, as part of the Chandra X-ray Visionary Project, the Galactic Center was observed using Chandra's High Energy Grating Spectrometer (HETGS) for a total of 3 Msec. These observations have provided an unparalleled view of the Galaxy's supermassive black hole and its surrounding environment. Due to the increased spectral resolution of the HETGS CCD detector we now have a better understanding of the nature of the extended quiescent emission from within the Bondi radius of the black hole. The grating spectrometer, with its much higher spectral resolution, promises an even more detailed look at the emission spectrum. However, significant diffuse emission spanning tens of arc-seconds around the central black hole has caused the quiescent grating spectrum to be background-dominated. This background must be properly understood and taken into account if we are to reap the benefits afforded by the HETGS. Here I describe some of the techniques used to deal with the background and discuss how the estimates of it are impacting the analysis of the grating spectrum of the quiescent emission. I acknowledge the participation of the Sgr A* XVP collaboration (sgra-star.com). This research is supported by NASA via Grant GO2-13110A and through the Smithsonian Astrophysical Observatory (SAO) contract SV3-73016 to MIT for support of the CXC and Science Instruments; the CXC is operated by SAO for and on behalf of NASA under contract NAS8-03060.

117.04 – Statistical Methods in XSPEC

Keith A. Arnaud¹

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I will review the statistical methods used in XSPEC and make recommendations.

117.05 – The HEASARC in 2013 and Beyond: NuSTAR, Astro-H, NICER...

Stephen A. Drake^{1, 2}, Alan P. Smale¹, Thomas A. McGlynn¹, Keith A. Arnaud^{1, 3}

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The High Energy Astrophysics Archival Research Center or HEASARC (<http://heasarc.gsfc.nasa.gov/>) is in its third decade as the NASA astrophysics discipline node supporting multi-mission cosmic X-ray and gamma-ray astronomy research. It provides a unified archive and software structure aimed both at 'legacy' missions such as Einstein, EXOSAT, ROSAT and RXTE, contemporary missions such as Fermi, Swift, Suzaku, Chandra, etc., and upcoming missions, such as NuSTAR, Astro-H and NICER. The HEASARC's high-energy astronomy archive has grown so that it presently contains 45 TB of data from 28 orbital missions. The HEASARC is the designated archive which supports NASA's Physics of the Cosmos theme (<http://pcos.gsfc.nasa.gov/>). We discuss some of the upcoming new initiatives and developments for the HEASARC, including the arrival of public data from the hard X-ray imaging NuSTAR mission in the summer of 2013, and the ongoing preparations to support the JAXA/NASA Astro-H mission and the NASA MoO Neutron Star Interior Composition Explorer (NICER), which are expected to become operational in 2015-2016. We also highlight some of the new software capabilities of the HEASARC, such as Xamin, a next-generation archive interface which will eventually supersede Browse, and the latest update of XSPEC (v 12.8.0).

117.06 – Application of an Improved Event Reconstruction and Imaging Approach for Compton Telescopes to Crab Measurements by NCT and COMPTEL Using MEGAlib

Andreas Zoglauer¹, Steven E. Boggs¹

1. UC Berkeley, Berkeley, CA, United States.

The analysis of data measured by Compton telescopes in space faces three key challenges. First, the path of the photons in the detectors has to be determined. Second, event selections have to be applied which maximize the sensitivity of the instrument. Finally, an image has to be reconstructed from the measured photons, which takes into account as much information of the response of the instrument as possible and recovers the flux of the observed sources. However, high background conditions and a response which is so complex that it only can be determined via Monte-Carlo simulations from limited calibrations complicate the analysis. The latest observations of Crab in the MeV range with a Compton telescope have been performed during the 2009 balloon flight of the Nuclear Compton Telescope NCT, and as well as with COMPTEL in the 1990's. Here we take a look at the data with the latest version of the MEGAlib data analysis tool. It allows to reconstruct the path the photon in the detectors and to suppress background events using a detailed Bayesian model selection approach, and allows using a high dimensional data space during image reconstruction based on a list-mode maximum-likelihood expectation-maximization approach. In the presentation we will explain the latest improvements to the approaches, modeling of polarization in the Bayesian event reconstruction and an improved exposure model for image reconstruction, and show results applying the methods to measurements of the Crab with the Nuclear Compton Telescope (NCT) and archival data of COMPTEL.

117.07 – Artificial Neural Networks as a Tool to Classify the 2FGL Unassociated Sources

David Salvetti¹

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Contributing teams: Fermi-LAT Collaboration

The Fermi Large Area Telescope Second Source Catalog (2FGL) lists positional, spectral, and temporal properties for 1873 gamma-ray sources detected during the first 24 months of operation in the 100 MeV to 300 GeV energy band. Approximately 30% of these sources remain 'unassociated', i.e. do not have any plausible known counterpart. The improved statistics from the LAT have enabled us to characterize each source with remarkable detail. We report on the use of Artificial Neural Networks (ANN) as a very promising method for understanding the nature of Fermi-LAT unassociated sources. This technique uses identified objects as a training sample, learning to distinguish each source class on the basis of parameters that describe its gamma-ray properties. By applying the algorithm to unknown objects, such as the unassociated sources, it is possible to quantify their probability of belonging to a specific class. We will present the ANN algorithm and discuss its application for classifying the 2FGL unassociated sources, its performance, and the advantages and disadvantages as compared with other classification schemes.

117.08 – Earth Occultation Imaging of the Low Energy Gamma-ray Sky with GBM

James Rodi¹, Michael L. Cherry¹, Gary L. Case^{1, 2}, Mark H. Finger⁴, Peter Jenke³, Colleen Wilson³, Ascension Camero-Arranz⁴, Vandiver Chaplin⁵

1. Louisiana State University, Baton Rouge, LA, United States. 2. La Sierra University, Riverside, CA, United States. 3. Marshall Space Flight Center, Huntsville, AL, United States. 4. NSSTC, Huntsville, AL, United States. 5. University of Alabama in Huntsville, Huntsville, AL, United States.

The Earth Occultation Technique (EOT) has been applied to the Fermi Gamma-ray Burst Monitor (GBM) to perform all-sky monitoring of a predetermined catalog of hard X-ray/soft gamma-ray sources. Imaging with a Differential filter using the Earth Occultation Method (IDEOM) has been developed to search for sources absent from the GBM catalog in order to complete the catalog and reduce a source of systematic error in the EOT analysis. With IDEOM, projections of the Earth's limb on the sky from the occultation of a source can be combined. These projections add constructively over the course of Fermi's orbital precession and thus localized a source. We present all-sky images that have been generated with IDEOM for ~ 4 years of GBM in the 12-50 keV, 50-100, and 100-300 keV energy ranges and the ~ 20 sources that have been added to the input source catalog through this method.

117.09 – Bayesian Methods in Sherpa

Aneta Siemiginowska¹, Thomas L. Aldcroft¹, Vinay Kashyap¹

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

Contributing teams: Chandra X-ray Center CIAO Team

Bayesian Framework for modeling the high energy astrophysics data has been implemented in Sherpa, a modeling and fitting application in CIAO. Sherpa is written in Python and the latest version can be installed and used with Python 2.7. We describe the concept of models with priors, the MCMC options for exploring the posterior probability distributions, and available algorithms for hypothesis testing and model selection. The methods correctly account for the Poisson nature of high energy astrophysics data from space-based X-ray and gamma-ray missions such as Chandra or Fermi. In most situations the modeling has to account for instrumental effects characterized by a probability of detecting photons of a given energy at a particular detector channel, or a particular location on the detector. We provide variety of examples based on the high energy data with ready to use recipes. Some future directions and potential linking with other Python packages will also be presented.

118 – Extragalactic Background

118.01 – The Contribution of BL Lacertae Objects to the Isotropic Gamma-ray Background

Marco Ajello¹, Dario Gasparri³, Michael Shaw², Roger W. Romani²

1. SSL, Berkeley, Berkeley, CA, United States. 2. Stanford, Stanford, CA, United States. 3. Agenzia Spaziale Italiana (ASI) Science Data Center, Roma, Italy.

Contributing teams: Fermi-LAT Collaboration

BL Lacertae (BL Lac) objects represent one of the most interesting source populations in the gamma-ray sky. Contrary to flat-spectrum radio quasars and even misaligned radio galaxies, the number of BL Lac objects detected by Fermi in its 'clean' samples is dramatically increasing, going from 275 objects detected in the first year to 395 in the second year. They include sources detected with a hard spectrum up to a redshift of ~ 2 . This population can thus provide a substantial contribution to the intensity of the Isotropic Gamma-ray Background (IGRB) at the highest (i.e., >10 GeV) energies. In this talk, I will review the properties of BL Lac objects at gamma-ray energies and current efforts to constrain their redshifts. I will also present the first luminosity function of gamma-ray selected BL Lac objects and an estimate of the contribution of this population to the IGRB. Implications for the formation of the >10 GeV background will also be discussed.

118.02 – The Impact of Gamma-ray Halos on the Angular Anisotropy of the Extragalactic Gamma-ray Background

Tonia M. Venters¹, Vasiliki Pavlidou²

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The study of the development of electromagnetic cascades in intergalactic magnetic fields (IGMF) serves as a robust probe into the strength and structure of these magnetic fields. Charged particles in electromagnetic cascades are deflected by magnetic fields giving rise to gamma-ray halos around extragalactic sources of VHE gamma rays (e.g., BL Lacertae-type objects). Such gamma-ray halos can have a profound impact on the intensity and angular properties of the contribution of extragalactic VHE sources to the extragalactic gamma-ray background (EGB) as measured by the Fermi-LAT at GeV energies. We demonstrate the impact of the deflection of cascades by the IGMF on the collective spectrum of extragalactic VHE sources, as well as the impact on the angular anisotropy of the EGB as a function of energy.

118.03 – Using Gamma Rays as Intergalactic Magnetometers

Justin Finke¹, Luis C. Reyes², Markos Georganopoulos³

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Contributing teams: Fermi-LAT Collaboration

Gamma rays from distant blazars interact with the extragalactic background light, creating electron-positron pairs, and reducing the amount of gamma-rays seen by ground-based atmospheric Cherenkov telescopes. These pairs can Compton-scatter the cosmic microwave background, creating a gamma-ray signature observable by the Fermi Large Area Telescope (LAT). The signature is also dependent on the intergalactic magnetic field (IGMF), since it can deflect the pairs from our line of sight, reducing the gamma-ray emission. We present preliminary constraints on the IGMF using Fermi-LAT and Cherenkov telescope observations, ruling out both very large and very small values of the IGMF strength.

119 – Future Prospects in X-ray Astronomy

119.01 – The Advanced X-ray Spectroscopic Imaging Observatory (AXSIO): Mission and Technology Overview

Jay A. Bookbinder¹, Randall K. Smith¹, Andrew Ptak², Robert Petre², Nicholas E. White², Joel N. Bregman³

1. Smithsonian Astrophysical Obs., Cambridge, MA, United States. 2. NASA's Goddard Space Flight Center, Greenbelt, MD, United States. 3. University of Michigan, Ann Arbor, MI, United States.

In September 2011 NASA released a Request for Information on “Concepts for the Next NASA X-ray Astronomy Mission” and formed a Community Science Team (CST) to help study the submitted concepts and evaluate their science return relative to the goals identified by the 2010 Astrophysics Decadal Survey “New Worlds, New Horizons” report. The CST report identified a number of candidate mission concepts that combine advances in large-area precision optics with new X-ray microcalorimeter technology. AXSIO reduces IXO's six instruments to two fixed detectors - the imaging X-ray Microcalorimeter Spectrometer and the X-ray Grating Spectrometer - while the final mission requirements (effective area, field of view, point spread function) retain some flexibility. We show how AXSIO will achieve most of IXO's science goals.

119.02 – AXSIO: The Science Return of a High-Resolution Spectroscopic X-ray Observatory

Randall K. Smith¹, Jay A. Bookbinder¹, Andrew Ptak³, Robert Petre³, Nicholas E. White³, Joel N. Bregman²

1. Smithsonian Astrophysical Observatory, Cambridge, MA, United States. 2. University of Michigan, Ann Arbor, MI, United States. 3. NASA's Goddard Space Flight Center, Greenbelt, MD, United States.

In September 2011 NASA formed a Community Science Team (CST) to study community-submitted “Concepts for the Next NASA X-ray Astronomy Mission” and evaluate their science return relative to the goals identified by the 2010 Astronomy & Astrophysics “New Worlds, New Horizons” Decadal survey. The science goals include observing the effects of strong gravity in black holes; mapping temperatures, abundances and dynamics in hot gas on scales ranging from the local ISM to galaxy clusters; observing feedback from AGN and star formation in galaxies; determining the fate of elusive baryonic matter in the galaxy halos and the IGM; and studying the structure of neutron stars. We demonstrate how AXSIO will achieve many of IXO's science goals, which require the high-throughput, high-resolution X-ray spectroscopy that AXSIO provides.

119.03 – Focal Plane Array Concept and Technologies for the X-Ray Microcalorimeter Spectrometer on the Advanced X-ray Spectroscopic Imaging Observatory (AXSIO)

Simon Bandler^{3, 2}, Joseph D. Adams^{3, 2}, Sarah E. Busch², James A. Chervenak², Megan E. Eckart^{3, 2}, Fred M. Finkbeiner²,

Caroline Kilbourne², Sang-Jun Lee², Frederick S. Porter², Jan-Patrick Porst^{3, 2}, John E. Sadleir², Stephen J. Smith^{3, 2}, William B.

Dorise¹, Joseph W. Fowler¹, Gene C. Hilton¹, Kent Irwin¹, Carl D. Reintsema¹, Joel N. Ullom¹

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We are developing large-format arrays of x-ray microcalorimeters to enable high-resolution, imaging X-ray imaging spectroscopy that meet the needs of the AXSIO mission. This mission requires microcalorimeter focal plane with an overall field of view of 4x4 arcmin and an energy resolution of better than 3 eV (or, a spectral resolving power of > 2000 at 6 keV) over part of the array. To achieve this, we are developing technologies to implement an overall array that consists of three components: a small, central inner array with very small pixels to purposely over-sample the x-ray beam to provide high spectral resolution (< 2eV) of nearby point sources, an intermediate array that has 6 arcsec pixels with better than 3 eV resolution, and an outer array that also has 6 arcsec pixels, but where multiple absorbers are read out by a single thermal sensor with better than 6 eV resolution for each pixel. Such a scheme will provide a field of view that will address the scientific requirements for extended sources and high spectral resolution with high throughput for bright sources, and compatible with existing cryogenic dewar technologies and capabilities. The technologies underlying this array approach are fully monolithic transition edge sensor microcalorimeters and multiplexed SQUID systems. We present device characterization of these array technologies, including uniformity of performance, sensitivity to environmental conditions, and thermal designs to minimize thermal cross-talk. We will describe our latest results in reading out these arrays using both time-domain and code-division multiplexing, and our strategy to use these technologies to design the microcalorimeter instrument for AXSIO with optimal performance and engineering margin.

119.04 – Developments in Off-Plane X-ray Reflection Grating Spectrometers

Randall L. McEntaffer¹

1. University of Iowa, Iowa City, IA, United States.

Contributing teams: Off-Plane X-ray Grating Spectrometer (OP-XGS) Team

X-ray reflection gratings have significant flight heritage from suborbital rockets to XMM-Newton. The off-plane mount is a configuration capable of obtaining the high throughput, high spectral resolving power requirements necessary for achieving key science goals in future NASA Explorer missions and Observatories. We detail the current state of off-plane gratings and highlight recent results in performance testing. We discuss the major difficulties involved with spectrometer development and plans on dealing with these issues. Finally, we present our future plans and a roadmap for technology development.

119.05 – Critical-angle Transmission Grating Development for AXSIO

Mark W. Bautz¹, Ralf K. Heilmann¹, Mark Schattenburg¹, Herman L. Marshall¹, David Huenemoerder¹, Daniel Dewey¹, Norbert S.

Schulz¹, John E. Davis¹

1. MIT, Cambridge, MA, United States.

Large area, high resolving power spectroscopy in the soft x-ray band can at present only be achieved with a state-of-the-art diffraction grating spectrometer. Recently developed critical-angle transmission (CAT) gratings combine the advantages of transmission gratings (low mass, relaxed figure and alignment tolerances) and blazed reflection gratings (high broad band diffraction efficiency, utilization of higher diffraction orders). Several new mission concepts containing CAT grating based spectrometers such as AXSIO promise to deliver unprecedented order-of-magnitude improvements in soft x-ray spectroscopy figures of merit. The CAT grating principle has previously been demonstrated with x rays using small wet-etched samples. We report the latest progress in the fabrication and testing of large (32x32 mm²) CAT grating prototypes with an integrated hierarchy of low-obstruction support structures. The gratings are fabricated from silicon-on-insulator wafers using advanced lithography and highly anisotropic dry and wet etching techniques. We present our latest grating

fabrication results.

119.06 – Laboratory Progress Toward a Soft X-ray Polarimeter

Herman L. Marshall¹, Norbert S. Schulz¹, Ralf K. Heilmann¹

1. MIT, Cambridge, MA, United States.

We present an instrument design capable of measuring linear X-ray polarization over a broad-band using conventional spectroscopic optics. A set of multilayer-coated flats reflects the dispersed X-rays to the instrument detectors. The intensity variation with position angle is measured to determine three Stokes parameters: I, Q, and U – all as a function of energy. By laterally grading the multilayer optics and matching the dispersion of the gratings, one may take advantage of high multilayer reflectivities and achieve modulation factors >50% over the entire 0.2 to 0.8 keV band. This instrument could be used in a small suborbital mission or adapted for use in an orbiting satellite to complement measurements at high energies. We present progress on laboratory work to demonstrate the capabilities of key components.

119.07 – X-Ray Polarimetry of Neutron Stars from a CubeSat

Philip Kaaret¹

1. Univ. of Iowa, Iowa City, IA, United States.

The propagation of radiation in the intense magnetic fields surrounding neutron stars is strongly affected by the fundamental quantum mechanical properties of photons and electrons as described by the theory of quantum electrodynamics (QED). Measurement of the polarization of X-rays emitted from the surface of a highly magnetized neutron star will unambiguously verify (or reject) a unique signature of strong-field QED and probe the neutron star magnetic field and X-ray emission geometry. We describe an instrument capable of measuring the polarization of soft X-rays from thermally-emitting isolated neutron stars that can be accomplished at modest cost by exploiting CubeSats as novel vehicles for high energy astrophysics.

119.08 – Supergiant Fast X-ray Transients: A Case Study for LOFT

Patrizia Romano¹, Vanessa Mangano¹, Enrico Bozzo², Paolo Esposito³, Carlo Ferrigno²

1. INAF-IASF Palermo, Palermo, Italy. 2. ISDC, Geneva, Switzerland. 3. INAF-IASF Milano, Milano, Italy.

LOFT, the Large Observatory For X-ray Timing, is a new space mission concept selected by ESA in February 2011 and currently competing for a launch of opportunity in 2022. LOFT will carry a coded mask Wide Field Monitor (WFM) and a 10-m² class collimated X-ray Large Area Detector (LAD) operating in the energy range 2-80 keV. The instruments on-board LOFT will dramatically deepen our knowledge of Supergiant Fast X-ray Transients, a class of High-Mass X-ray Binaries whose optical counterparts are O or B supergiant stars, and whose X-ray outbursts are about 4 orders of magnitude brighter than the quiescent state. The LAD and the WFM will provide simultaneous high S/N broad-band and time-resolved spectroscopy in several intensity states, long term monitoring that will yield new determinations of orbital periods, as well as spin periods. We show the results of an extensive set of simulations based on the Swift broad-band and detailed XMM-Newton observations we collected up to now. Our simulations describe the outbursts at several intensities ($F(2-10 \text{ keV})=5.9\text{E}-9$ to $5.5\text{E}-10 \text{ erg cm}^{-2} \text{ s}^{-1}$), the intermediate and most common state ($1\text{E}-11 \text{ erg cm}^{-2} \text{ s}^{-1}$), and the low state ($1.2\text{E}-12$ to $5\text{E}-13 \text{ erg cm}^{-2} \text{ s}^{-1}$). We also considered large variations of NH and the presence of emission lines, as observed by Swift and XMM-Newton. We acknowledge financial contribution from ASI-INA F I/004/11/0 and I/021/12/0.

120 – Galaxies, ISM

120.02 – In Search of Bok Globules in the X-Ray

Michael L. McCollough¹

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In a recent analysis of Chandra data there was presented the first ever detection of a Bok Globule in the X-ray. The X-rays observed were the result of the scattering of X-rays off of the cloud. This was possible due to the Bok Globule being close to the line-of-sight of a bright X-ray source (Cygnus X-3). In this presentation we will examine the range of possible scattering parameters which one may expect for such features and will discuss the possibility of observing other Bok Globules. We will also discuss the spectral and temporal characteristics that one might be able to observe for such features.

120.03 – Revisiting the Interstellar Abundances Toward X Per

Lynne A. Valencic^{1, 2}, Randall K. Smith³

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The nearby X-ray binary X Per (HD 24534) is a useful beacon with which to measure elemental abundances in the local ISM and examine possible dust constituents. Spectra were obtained from Chandra Observatory's LETG/ACIS-S and XMM-Newton's RGS instruments. The absorption features of O, Mg, Si, and Fe were examined and column densities were found. The abundances are similar to those of commonly-used abundance references. Further, MgSiO₃ may be a significant absorber at the O, Si, and Mg K edges, while metallic iron and oxides may contribute to absorption at the Fe L edge.

120.04 – Dynamics of Astrophysical Bubbles and Bubble-Driven Shocks: Basic Theory, Analytical Solutions and Observational Signatures

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Bubbles in the interstellar medium are produced by astrophysical sources, which continuously or explosively deposit large amount of energy into the ambient medium. These expanding bubbles can drive shocks in front of them, which dynamics is markedly different from the widely used Sedov-von Neumann-Taylor blast wave solution. Here we present the theory of a bubble-driven shock and show how its properties and evolution are determined by the temporal history of the source energy output, generally referred to as the *source luminosity law*, $L(t)$. In particular, we find the analytical solutions for a driven shock in two cases: the self-similar scaling $L \sim (t/t_s)^p$ law (with p and t_s being constants) and the finite activity time case, $L \sim (1-t/t_s)^{-p}$. The latter with $p > 0$ describes a finite-time-singular behavior, which is relevant to a wide variety of systems with explosive-type energy release. For both luminosity laws, we derived the conditions needed for the driven shock to exist and predict the shock observational signatures. Our results can be relevant to stellar systems with strong winds, merging neutron star/magnetar/black hole systems, and massive stars evolving to supernovae explosions.

120.05 – The Low Metallicity ISM

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We present the results from our cosmological simulations of the low metallicity ISM. The first generation of stars in the universe synthesized the first metal during their stellar evolution. Later, the newly forged metal was dispersed to the primordial gas through supernova explosions and formed into the low metallicity ISM. We use cosmological simulations considering the relevant physical processes of early universe to study the formation of low metallicity ISM. For better modeling the physical and chemical properties of the low metallicity ISM, we apply the realistic stellar feedback by using updated stellar models of the first stars and supernovae in our cosmological simulations. Our simulations take the initial conditions from the WMAP data, evolve through the birth of the first ever star and its supernova, until the low metallicity ISM formed. We will discuss the chemical enrichment inside the low metallicity environment and its relation to the later star formation.

120.07 – Probing the Anisotropy of Warm-Hot Gaseous Halo of the Milky Way

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Most of the baryons from galaxies have been "missing" and several studies have attempted to map the Circum-Galactic Medium (CGM) or Galactic halo of galaxies in their quest. The characterization of the CGM is necessary for any detailed understanding of galaxy formation and evolution. Recently using the X-ray observations made with the Chandra X-ray Observatory we probed the warm-hot phase of the CGM of our Milky Way at about 10⁶ K. We have detected OVII and OVIII absorption lines at $z=0$ in extragalactic sight lines and measure accurate column densities using both K α and K β lines of OVII. We then combined these measurements with the emission measure of the Galactic halo from literature and showed that the warm-hot phase of the CGM is massive, extending over a large region around the Milky Way, with a radius of over 100 kpc. The mass content of this phase is over ten billion solar masses, many times more than that in cooler gas phases and comparable to the total baryonic mass in the disk of the Galaxy. Now extending our efforts to characterize the CGM, we used the X-ray emission measures close to the sight-lines of absorption lines, instead of an average emission measure used in previous studies. This will allow us to probe anisotropy of the warm-hot gas of the Galactic halo. Here I will discuss these observations and argue for an extended warm-hot gas in the CGM, a candidate for the Galactic "missing baryons".

120.08 – Missing Baryons in Galaxies

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Most of the baryons are retained in rich galaxy clusters (measured relative to the dark matter mass), but in some of the poorer groups appear to be missing a significant fraction of baryons. This trend of decreasing baryon content continues through galaxies, where the Milky Way is missing about 75% of its baryons and the typical (lower mass) galaxy is missing 90% of its baryons. We investigated this missing baryon problem for galaxies by determining the hot gas content of galaxies in very extended halos. These studies include the identification of modest mass hot gaseous halos around the Milky Way (out to at least 20 kpc), around two extremely massive spirals (to at least 50 kpc), and in a stacked set of L* galaxies. These halos are unlikely to contain the missing baryons around

galaxies, which likely exist in halos that extend beyond the virial radius.

120.10 – The Mass Profiles of Early-type Galaxies from X-ray and Optical Constraints

Aaron J. Romanowsky^{1, 2}, Jean P. Brodie², Kristin Woodley², Jacob Arnold², Duncan Forbes³, Zachary Jennings²

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Contributing teams: SAGES Team

The two primary methods for measuring the dark matter profiles of nearby early-type galaxies are from X-ray emitting gas and from optical kinematic tracers such as integrated starlight, globular clusters, and planetary nebulae. There has never been a systematic comparison of the mass inferences obtained from the two different approaches, but the few cases examined in the literature have yielded some remarkable discrepancies. A new opportunity is now available to study this issue carefully using a large sample of galaxies, as the 'SLUGGS' Keck-based survey of wide-field galaxy kinematics nears completion. I will present initial comparisons of X-ray and optical masses for several galaxies, and discuss possible implications for the pressure support and dynamical state of these galaxies.

120.11 – Hot Gas and Nuclear X-ray Emission from Early Type Galaxies

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Using Chandra observations of 200 early-type galaxies, we determine their gas masses, the X-ray luminosities of supermassive black holes in their nuclei, and the frequency of multiple supermassive black holes as a function of galaxy mass. We find that extended X-ray emission from hot gas is nearly universal in luminous, massive galaxies, but very rare in optically faint galaxies. We also find that nuclear X-ray emission is common in galaxies of all masses and is correlated with the nuclear radio emission.

120.12 – X-ray Scaling Relation of Early Type Galaxies

Dong-Woo Kim¹

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Based on the previous results by Borason, Kim & Fabbiano (2011), we revisit the scaling relations of early type galaxies with a large sample of early type galaxies. The scaling relations can be directly compared with theoretical models to better understand the evolution of the galaxies and their hot ISM. We address the implications of our results in terms of theoretical predictions of the dynamical states of hot halos.

120.13 – Hard X-ray Emission from the Arches Cluster Region Observed with NuSTAR

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Contributing teams: NuSTAR Team

The Arches cluster is a young, densely packed massive star cluster in our Galaxy, showing high level of star formation activity. The X-ray emission from the cluster is a mix of thermal and nonthermal radiation. The thermal emission is thought to arise from collisions between the strong winds of massive stars. The nonthermal diffuse emission prominent in the iron K_{alpha} line emission at 6.4 keV, detected in the broad area around the cluster, may be produced by the interaction of low-energy cosmic-ray electrons and ions with neutral ambient gas. The diffuse 6.4 keV fluorescent line emission may be also the result of the irradiation of cold matter by hard X-rays photons. Previously, the lack of spectral measurements above 10 keV did not allow for a definitive conclusion about the ionizing mechanism. Thanks to the recently launched NuSTAR mission, we performed the first imaging and spectral measurements of the Arches cluster at energies above 10 keV. Preliminary analysis of the NuSTAR data shows that hard X-ray emission is extended in the broad region around the cluster where the 6.4 keV iron line is observed. The details of the analysis and possible interpretation will be discussed in this presentation.

120.15 – Getting a Good, Hard X-ray Look at Starburst Galaxies with NuSTAR

Andrew Ptak¹, Meg Argo², Keith Bechtol³, Steven E. Boggs⁴, Finn Christensen⁵, William W. Craig⁴, Charles J. Hailey⁶, Fiona Harrison⁷, Ann E. Hornschemeier¹, Bret Lehmer^{1, 8}, Jean-Christophe Leyder^{1, 12}, Thomas J. Maccarone⁹, Daniel Stern¹⁰, Tonia M. Venters¹, Daniel R. Wik¹, Andreas Zezas¹¹, William Zhang¹

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Contributing teams: NuSTAR Team

Hard X-ray emission from star-forming galaxies arises from a population of neutron stars and stellar-mass (and possibly intermediate-mass) black holes, however few starburst galaxies have been detected above 10 keV. The recent launch of NuSTAR, the first satellite with hard X-ray focusing optics, opens up the possibility to not only detect these objects above 10 keV for the first time but also characterize their hard X-ray properties. Here we present an overview of a NuSTAR program to survey five normal/starburst galaxies: M82, M83, NGC 3256, NGC 3310 and Arp 299 and data analysis strategies. These observations will be supplementing a NuSTAR-Chandra-VLBA campaign on NGC 253. The NuSTAR observation of M82 will likely be dominated by the ULX M82 X-1. The exposure times will range from 30 to 180 ks, with the exposure set to ensure a 10-20 keV 5-sigma detection under conservative assumptions and these observations will more likely result in strong detections of at least the brightest several sources in each galaxy. The main goals are: 1) characterize the typical starburst spectrum above 10 keV 2) identify the nature of individually-detected X-ray sources (neutron star HMXB vs. black hole candidate) 3) look for short-term (hours to weeks) variability and establish a baseline for long-term variability studies (weeks to years) 4) characterization of the unresolved contribution to the NuSTAR flux (unresolved X-ray binaries and 'diffuse' emission such as inverse-Compton scattering off of cosmic rays)

120.16 – Spatial Analysis of the Hot Gas Distribution in a Complete Chandra Survey of Early-Type Galaxies

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The amount of hot X-ray-emitting gas in early-type galaxies is thought to be indicative of the hydrodynamic state of the gas, with gas being more easily removed from galaxies with lower mass and/or stronger Type Ia supernovae-driven winds. Escaping gas should lead to more an extended gaseous X-ray emission profile than in galaxies with deep enough potential wells to retain the gas. We search for a correlation between the amount of hot gas and the slope of the hot gas surface brightness profile (normalized by the optical light) for a complete survey of optically bright early-type galaxies observed by Chandra in order to test the accuracy of wind-driven galactic models.

121 – Gravity Waves

121.01 – Electromagnetic Counterparts to Supermassive Black Hole Mergers

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Future space-based gravitational-wave observations will provide an entirely new channel of information about the massive black holes marking the hearts of merging galaxies. The complementarity of gravitational-wave information with that from existing and future electromagnetic observations may enable strong astrophysical inferences to be drawn from future multimessenger observations, if they can be achieved. We discuss numerical simulations of transient electromagnetic signatures associated with massive black hole mergers, which include strong X-ray components. If such transients exist, the relative scarcity of bright X-ray sources, may lead to greater opportunities for multimessenger associations even for relatively poorly located gravitational-wave events. Understanding this possibility also requires better characterization of the transient X-ray sky.

121.02 – Prospects for GW Transients in Early Advanced LIGO and Virgo Science Runs

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Contributing teams: LIGO Scientific Collaboration, Virgo Collaboration

Currently under construction, second generation ground-based gravitational-wave detectors Advanced LIGO and Advanced Virgo are expected to begin science operations in the second half of this decade. Based on predicted rates for compact binary mergers (neutron star – neutron star, neutron star – black hole, black hole – black hole) coupled with their projected strain sensitivities, Advanced LIGO and Advanced Virgo are expected to yield the first direct observations of gravitational waves. A network of at least three well-separated interferometers can rapidly ‘triangulate’ a gravitational-wave source by timing the arrival of gravitational waves, allowing for coincident observations with electromagnetic telescopes. Thus, sky localization of gravitational-wave events for rapid electromagnetic follow-up is one of the primary scientific motivations for operating the Advanced LIGO-Virgo network. In this presentation, I will describe the currently projected schedule, sensitivity, and sky localization accuracy for the GW detector network in the next decade.

121.03 – Proposed Atom Interferometry Gravitational Wave Measurements Over a Single Baseline

Peter L. Bender¹

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A recent paper by Graham et al. [1] proposed gravitational wave measurements using an atom interferometer at each end of a single baseline between two spacecraft. The suggested approach makes use of extremely narrow linewidth single photon transitions, such as the 698 nm clock transition in Sr-87. A case discussed has a $L = 500$ km baseline length between spacecraft, $N = 300$ large momentum transfer beamsplitters, and a total measurement time of 100 s. The authors point out that many sources of errors in measuring GW signals cancel because they are nearly the same for both parts of the split atom wave functions and/or for both interferometers. Thus a much reduced sensitivity to laser frequency noise is reported. However, it seems that the requirements on this kind of mission are still very demanding. For example, large differences in phase between the 2 parts of the wave function for each interferometer are expected due to jitter in the timing of the laser pulses. This makes it more difficult to determine the sign of the desired GW signals. And, if the atom cloud temperature of 100 pK and the Rabi frequency of 500 Hz considered in previous papers are assumed, the fraction of the atoms contributing to the final signal would be small. This is because of the total of 2,400 successful state transitions required for each half of the wave function if $N = 300$ LMT beamsplitters are used. [1] P. W. Graham, J. M. Hogan, M. A. Kasevich, and S. Rajendran, arXiv:1206.0818v1 [gr-qc] 5 Jun 2012.

121.04 – A Possible U.S. Contribution to eLISA, a Gravitational-Wave Mission Concept for ESA’s L2 Opportunity

Robin T. Stebbins¹

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Scientists from the member states of the European Space Agency (ESA) that proposed the New Gravitational Wave Observatory (NGO) have organized the eLISA Consortium to propose for ESA’s next large mission opportunity, called L2. The Evolved Laser Interferometer Space Antenna (eLISA) concept is derived from the well studied LISA concept for a space-based, gravitational-wave mission. eLISA will use the technology being developed in the LISA Pathfinder mission in a two-arm version that achieves much of the LISA science endorsed by the Decadal Survey. If invited, NASA could join the project as a junior partner with a ~15% share. This could enable a third arm and substantially augment the science return. While the details of the eLISA concept to be proposed have not yet been finalized, the SGO Mid concept, recently studied in the U.S., constitutes a possible augmented concept for an ESA/NASA partnership. The eLISA concept and the SGO Mid concept are described and compared.

122 – Lab Astro

122.01 – Atomic Data for Astrophysics: Measurements of Electron Impact Ionization Using an Ion Storage Ring

Daniel W. Savin¹, Michael Hahn¹, Arno Becker^{2, 3}, Dietrich Bernhardt², Manfred Grieser³, Claude Krantz³, Michael Lestinsky⁴, Alfred Mueller², Oldrich Novotny¹, Roland Reppow³, Stefan Schippers², Kaija Spruck², Andreas Wolf³

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Understanding the solar atmosphere hinges, in part, on knowledge of the underlying atomic physics responsible for the charge state distribution (CSD) of the plasma. This in turn requires reliable electron impact ionization (EII) cross sections which are needed to calculate accurate CSDs for electron ionized objects such as stars, supemovae, galaxies, and clusters of galaxies. We are studying EII for astrophysically important ions using the TSR storage ring located at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. Storage ring measurements are largely free of the metastable contamination found in other experimental geometries, resulting in unambiguous EII cross section data. We have found discrepancies of 10% - 30% between the measured cross sections and those commonly used in CSD models. Because it is impractical to perform experimental measurements for every astrophysically relevant ion, theory must provide the bulk of the needed EII data. These experimental results provide an essential benchmark for such EII calculations.

122.02 – Laboratory Measurements of the Relative Oscillator Strengths of the Fe XVII Lines 3C and 3D Using an X-ray Laser and an Electron Beam Ion Trap

Gregory V. Brown¹

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Contributing teams: Hi-Light Collaboration

X-ray emission from neon-like Fe XVII has been observed in a plethora of celestial sources including stellar atmospheres, galaxy clusters, elliptical galaxies, and supemova remnants. Two of the strongest lines emitted from Fe XVII are the 3d to 2p transitions located at 15.01 and 15.26 angstroms and known as 3C and 3D, respectively. Owing to their strength and presence over a large temperature range, diagnostics involving these lines are of high value. Unfortunately, even though many theoretical and experimental studies have been conducted on 3C and 3D, significant discrepancies among different theories, and between theory and both laboratory and observational measurements have been found. Many different theoretical approaches have been pursued in attempt to resolve the discrepancies, but none has provided a consistent solution (Brown & Beiersdorfer Physical Review Letters, 2012). As a result, the diagnostic utility of these lines has not been fully realized. In order to further probe the nature of these X-ray transitions, we have used the Linac Coherent Light Source X-ray free electron laser in conjunction with the portable FLASH-EBIT electron beam ion trap to photo-excite these lines and measure their relative oscillator strength, R_o . Our results, $R_o = 2.61 \pm 0.23$ (Bemitt, et al. Nature 2012) differs by over 3% from the best quantum mechanical calculations. We present an overview of these measurements and their implications, as well as a sampling of other photoabsorption measurements using the FLASH-EBIT at various third and fourth generation light sources. This work was performed under the auspices of the U.S. D.o.E. by under Contract DE-AC52-07NA27344 and supported by NASA grants to LLNL and GSFC.

122.03 – Low Charge States of Si and S: from Cygnus X-1 to the Lab and Back

Natalie Hell^{1, 2}, Ivica Miškovič¹, Manfred Hanke¹, Gregory V. Brown², Joern Wilms¹, Joel Clementson^{2, 3}, Peter

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The X-ray light curves of the high mass X-ray binary (HMXB) Cygnus X-1 are shaped by strong, relatively short, absorption dips. While spectra extracted from the dip free phases are dominated by absorption lines of the Rydberg series of H- and He-like ions, 1s²2p transitions of lower ionized Si and S appear in the dip spectra. This shift in charge balance suggests that we probe “clumps” of cold material embedded in the companion's stellar wind as they cross our line of sight. Determining the bulk motion of these clumps by measuring the Doppler shifts of these lines as a function of dipping strength and ionization state can confirm this theory. Unfortunately, the predicted uncertainty for theoretical calculations – if available at all – is of the order of the expected shifts in the system. To overcome this lack of reliable reference wavelengths, we measured the K α spectra of H- through F-like Si and S with the EBIT Calorimeter Spectrometer (ECS) and the Lawrence Livermore National Laboratory electron beam ion trap EBIT-I. We then directly apply these new line centers to calculate the Doppler shifts of the lines observed in Cygnus X-1. With this approach, we find shifts consistent with constant velocity of the absorber throughout all ionization states and, hence, provide evidence for an onion-like ion structure of the clumps. Funded by BMWi under DLR grant 50OR1207. Work at LLNL was performed under the auspices of DOE under contract DE-AC52-07NA27344 and supported by NASA grants.

122.04 – Extreme Ultraviolet Emission Lines of Iron Fe XI-XIII

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The extreme ultraviolet (EUV) spectral region (ca. 20–300 Å) is rich in emission lines from low- to mid-Z ions, particularly from the middle charge states of iron. Many of these emission lines are important diagnostics for astrophysical plasmas, providing information on properties such as elemental abundance, temperature, density, and even magnetic field strength. In recent years, strides have been made to understand the complexity of the atomic levels of the ions that emit the lines that contribute to the richness of the EUV region. Laboratory measurements have been made to verify and benchmark the lines. Here, we present laboratory measurements of Fe XI, Fe XII, and Fe XIII between 40–140 Å. The measurements were made at the Lawrence Livermore electron beam ion trap (EBIT) facility, which has been optimized for laboratory astrophysics, and which allows us to select specific charge states of iron to help line identification. We also present new calculations by the Hebrew University - Lawrence Livermore Atomic Code (HULLAC), which we also utilized for line identification. We found that HULLAC does a creditable job of reproducing the forest of lines we observed in the EBIT spectra, although line positions are in need of adjustment, and line intensities often differed from those observed. We identify or confirm a number of new lines for these charge states. This work was supported by the

122.05 – Magnetized Collisionless Shock Studies Using High Velocity Plasmoids

Thomas Weber¹, Thomas Intrator¹

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Magnetized collisionless shocks are ubiquitous throughout the cosmos and are observed to accelerate particles to relativistic velocities, amplify magnetic fields, transport energy, and create non-thermal distributions. They exhibit transitional scale lengths much shorter than the collisional mean free path and are mediated by collective interactions rather than Coulomb collisions. The Magnetized Shock Experiment (MSX) leverages advances in Field Reversed Configuration (FRC) plasmoid formation and acceleration to produce highly supersonic and super-Alfvénic supercritical shocks with pre-existing magnetic field at perpendicular, parallel or oblique angles to the direction of propagation. Adjustable shock speed, density, and magnetic field provide unique access to a range of parameter space relevant to a variety of naturally occurring shocks. This effort examines experimentally, analytically, and numerically the physics of collisionless shock formation, structure, and kinetic effects in a laboratory setting and draw comparisons between experimental data and astronomical observations. Supported by DOE Office of Fusion Energy Sciences and National Nuclear Security Administration under LANS contract DE-AC52-06NA25369
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122.06 – Magnetic Micro-turbulence: Relation of Electron Diffusion to Their Emitted Radiation Spectra

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Kinetic (e.g., Weibel-type) instabilities are ubiquitous in astrophysical high-energy density environments, e.g., in relativistic collisionless shocks and reconnection of strong magnetic fields in neutron star and magnetar magnetospheres, as well as in laboratory laser-produced plasmas. Such instabilities generate strong (sub-equibartition) magnetic fields which reside at small, sub-Larmor scales. Efficient electron acceleration to relativistic energies is not uncommon in such environments. Radiation emitted by these electrons in such fields, called the jitter radiation, exhibits spectra different from what is predicted by synchrotron theory. The small-scale fields also simultaneously affect the particle transport via pitch-angle diffusion. Both effects are interrelated and can be used to diagnose the astrophysical plasmas. Indeed, the radiation pattern is intimately related to the particle orbits and, thus, to the transport properties of the turbulence. We study such a relation between transport in and radiation from micro-scale turbulence via numerical simulations and analysis. We will present the results for both the relativistic and non-relativistic regimes – the former being important in astrophysical environments and the latter is of great importance to lab experiments.

122.07 – Laboratory Observation of Magnetic Field Growth Driven by Shear Flow

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We have measured in the laboratory profiles of magnetic flux ropes, that include ion flow, magnetic field, current density, and plasma pressure. The electron flows v_e can therefore be inferred, and we use this information to evaluate the Hall $J \times B$ term in a two fluid magnetohydrodynamic Ohm's Law. Mutually attracted and compressed flux ropes break the cylindrical symmetry. This simple and coherent example of shear flow supports magnetic field growth corresponding to non vanishing $\text{curl} \times v_e \times B$. In the absence of magnetic reconnection we measure and predict a quadrupole out of plane magnetic field B_z , even though this has historically been invoked to be the signature of Hall magnetic reconnection. This provides a natural and general mechanism for large scale sheared flows to acquire smaller scale magnetic features, disordered structure, and possibly turbulence. *Supported by DOE Office of Fusion Energy Sciences under LANS contract DE-AC52-06NA25369, NASA Geospace NNH10A044I, Basic

122.08 – Radiative Cooling of Non-equilibrium Ionization Plasmas Based on AtomDB

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The detail ionization state is difficult to know from observations, collisional ionization equilibrium (CIE) or simple parameterized ionizing assumption are usually applied in modeling. But such assumption doesn't work in some respects, e.g. for studying the overionized plasma which is recently confirmed in supernova remnants. We performed this work to study the different radiative cooling rates in CIE and non-equilibrium ionization (NEI) cases in detail, which is crucial in modeling the evolution of plasma in realistic cases. This work is based on the most developed atomic database, AtomDB v2.0.2 (see Foster et al. 2012, ApJ, 756, 128), and applied the companion APEC program for calculations. We focus on the hot optically thin gas, such as the diffuse interstellar medium. We present our primary results of CIE plasma in a density range of $1e-5 \text{ cm}^{-3}$ to $1e10 \text{ cm}^{-3}$ and a temperature range of $1e4 \text{ K}$ to $1e8 \text{ K}$, and for NEI plasma, both ionizing and recombining cases, in the same density and temperature ranges, with the initial ionization temperatures from $1e4 \text{ K}$ to $1e8$ and the ionization timescales from $1e0$ to $1e13 \text{ cm}^{-3}\text{s}$. There are 30 elements included in the calculation, from hydrogen to zinc. Detailed comparison between CIE and NEI plasma are shown. Further implication from such comparison are discussed.

123 – Missions and Instruments

123.01 – TeV Signatures of Fermi and IACT Sources Observed by Milagro

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Contributing teams: Milagro Collaboration

We perform targeted searches in Milagro data to detect TeV emissions from potential TeV-emitting candidates. Galactic candidates were GeV pulsars from the Fermi LAT second source catalog (2FGL) in the Milagro sky coverage ($77^\circ < \text{DEC} < 80^\circ$). Extragalactic candidates are selected from the 2FGL and from the Imaging Air Cerenkov Telescope (IACT) detections in the TeVCat catalog. Out of 52 pulsar targets, emission in the 1-100 TeV energy range is found coincident with 15 of them. We studied the TeV-GeV flux correlation of these observations. Among 709 extragalactic observations Markarian 421 was identified with a high statistical significance and three other AGNs were identified as potential TeV emitting sources with a flux just below our sensitivity threshold. Our measurements and comparisons of results with existing models will be presented in this talk.

123.02 – Monitoring the Hard X-ray/Soft Gamma-Ray Sky with Fermi/GBM – The First Four Years

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The Gamma ray Burst Monitor (GBM) on board Fermi Gamma-ray Space Telescope has been providing continuous data to the astronomical community since 2008 August 12. We have applied the Earth Occultation Technique (EOT) to monitor hard x-ray and soft gamma-ray sources in the 10-1000 keV energy range. The monitoring capability of GBM is unique in that it covers such a wide energy range, complementary to other monitoring instruments, and is the only monitoring instrument operating above about 100 keV. We recently published a 3-year catalog of 209 sources, 99 of which were positively detected above 10 keV and 9 of which were detected above 100 keV. Using the EOT, we also discovered the decrease in the Crab Nebula flux that occurred between the middle of 2008 and the middle of 2010. We continue to monitor transient and/or active sources such as Cygnus X-1, which has been in a period of increased activity for the last 2010. We have also developed an imaging technique that allows us to search for sources that need to be added to our monitoring catalog. We present highlights of the 3-yr catalog as well as an update on the current status of the monitoring catalog, an update on the Crab Nebula light curve and spectrum, light curves and spectra of Cygnus X-1 during its activity, and images from the EOT all-sky imaging.

123.04 – Twelve Years of Education and Public Outreach with the Fermi Gamma-ray Space Telescope

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Contributing teams: Fermi E/PO Team

During the past twelve years, NASA's *Fermi Gamma-ray Space Telescope* has supported a wide range of Education and Public Outreach (E/PO) activities, targeting K-14 students and the general public. The purpose of the *Fermi* E/PO program is to increase student and public understanding of the science of the high-energy Universe, through inspiring, engaging and educational activities linked to the mission's science objectives. The E/PO program has additional more general goals, including increasing the diversity of students in the Science, Technology, Engineering and Mathematics (STEM) pipeline, and increasing public awareness and understanding of *Fermi* science and technology. *Fermi*'s multi-faceted E/PO program includes elements in each major outcome category: ? Higher Education: *Fermi* E/PO promotes STEM careers through the use of NASA data including research experiences for students and teachers (Global Telescope Network), education through STEM curriculum development projects (Cosmology curriculum) and through enrichment activities (Large Area Telescope simulator). ? Elementary and Secondary education: *Fermi* E/PO links the science objectives of the *Fermi* mission to well-tested, customer-focused and NASA-approved standards-aligned classroom materials (Black Hole Resources, Active Galaxy Education Unit and Pop-up book, TOPS guides, Supernova Education Unit). These materials have been distributed through (Educator Ambassador and on-line) teacher training workshops and through programs involving under-represented students (after-school clubs and Astro 4 Girls). ? Informal education and public outreach: *Fermi* E/PO engages the public in sharing the experience of exploration and discovery through high-leverage multi-media experiences (Black Holes planetarium and PBS NOVA shows), through popular websites (Gamma-ray Burst Skymap, *Epo's Chronicles*), social media (Facebook, MySpace), interactive web-based activities (Space Mysteries, Einstein@Home) and activities by amateur astronomers nation-wide (Supernova! Toolkit). This poster highlights various facets of the *Fermi* E/PO program.

123.05 – The NuSTAR Education and Public Outreach Program

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Contributing teams: NuSTAR Team

NuSTAR is a NASA Small Explorer mission led by Caltech, managed by JPL, and implemented by an international team of scientists and engineers, under the direction of CalTech Professor Fiona Harrison, principal investigator. *NuSTAR* is a pathfinder mission that is opening the high-energy X-ray sky for sensitive study for the first time. By focusing X-rays at higher energies (up to 79 keV) *NuSTAR* will answer fundamental questions about the Universe: How are black holes distributed through the cosmos? How were the elements that compose our bodies and the Earth forged in the explosions of massive stars? What powers the most extreme active galaxies? Perhaps most exciting is the opportunity to fill a blank map with wonders we have not yet dreamed of: *NuSTAR* offers the opportunity to explore our Universe in an entirely new way. The purpose of the *NuSTAR* E/PO program is to increase understanding of the science of the high-energy Universe, by capitalizing on the synergy of existing high-energy astrophysics E/PO programs to support the mission's objectives. Our goals are to: facilitate understanding of the nature of collapsed objects, develop awareness of the role of supernovae in creating the chemical elements and to facilitate

understanding of the physical properties of the extreme Universe. We will do this through a program that includes educator workshops through NASA's Astrophysics Educator Ambassador program, a technology education unit for formal educators, articles for *Physics Teacher* and/or *Science Scope* magazines, and work with informal educators on a museum exhibit that includes a model of *NuSTAR* and describes the mission's science objectives. Extensive outreach is also underway by members of the Science Team, who are working with high school students, undergraduates and graduate students. We are also developing printed materials that describe the mission and special workshops for girls at public libraries in order to improve the STEM pipeline.

123.06 – Performance, Goals, and Status of the Upcoming Nuclear Compton Telescope Balloon Campaigns

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The Nuclear Compton Telescope (NCT) is a wide-field gamma-ray imager utilizing state of the art, cross-strip germanium detectors for Compton imaging of astrophysical sources. NCT underwent a prototype flight in 2005 to verify the instrumental background, and a first-light ConUS flight in 2009 which resulted in a detection of the Crab nebula as a verification of the instrument sensitivity. Unfortunately, a launch mishap during NCT's first science campaign in 2010 left the instrument largely destroyed. A rebuild of the NCT instrument is currently underway with an expected return to flight readiness in late 2013. The rebuilt NCT detector system is comprised of twelve high-purity germanium detectors and an active CsI scintillator shield. The cryogenics system has been redesigned and now employs a cryocooler, which, along with an all-new, low-mass gondola, qualifies NCT to fly on the Ultra Long Duration balloon (ULDB) platform. ULDB flights may last up to 100 days, effectively improving NCT's sensitivity over the course of a flight and opening up new science opportunities. The NCT collaboration is currently proposing to NASA for the science flight program, which will include an LDB flight from Kiruna, Sweden in 2014 and a ULDB flight from Wanaka, New Zealand in 2016. MEGALIB/GEANT4 simulations of the instrument were performed for the two launch scenarios and the instrument performance was determined. Primary science goals for the NCT balloon flights include mapping of the galactic bulge/disk positron annihilation line at 511 keV in order to shed light on the positron source(s), mapping of ²⁶Al (1.809 MeV) and ⁶⁰Fe (1.173 MeV and 1.333 MeV) emission to uncover the galactic history of core-collapse supernovae, and detection and measurement of polarization from gamma-ray bursts.

123.07 – The Black Hole Evolution and Space Time (BEST) Observatory

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In this contribution, we present the concept of a next-generation X-ray mission called BEST (Black hole Evolution and Space Time). The mission concept uses a 3000 square centimeter effective area mirror (at 6 keV) to achieve unprecedented sensitivities for hard X-ray imaging spectrometry (5-70 keV) and for broadband X-ray polarimetry (2-70 keV). BEST can make substantial contributions to our understanding of the inner workings of accreting black holes, our knowledge about the fabric of extremely curved spacetime, and the evolution of supermassive black holes. BEST will allow for time resolved studies of accretion disks. With the large mirror area and broad bandpass, BEST will allow for high-sensitivity X-ray spectropolarimetry: it will probe the time variability of the X-ray polarization from stellar mass and supermassive black holes, and it will measure the polarization properties in 30 independent energy bins. These capabilities will allow BEST to conduct tests of accretion disk models and the underlying spacetimes. With three times larger mirror area and ten times better angular resolution than *NuSTAR*, BEST will be able to make deep field observations with a more than 15 times better sensitivity than *NuSTAR*. The mission will be able to trace the evolution of obscured and unobscured black holes in the redshift range from zero to six, covering the most important epoch of supermassive black hole growth. The hard X-ray sensitivity of BEST will enable a deep census of non-thermal particle populations. BEST will give us insights into AGN feedback by measuring the particle luminosity injected by AGNs into the interstellar medium (ISM) of their hosts, and will map the emission from particles accelerated at large scale structure shocks. Finally, BEST has the potential to constrain the equation of state of neutron stars (NS).

123.08 – Critical Developments Toward Building Laue Lenses for Gamma-Ray Astronomy

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In astrophysics, the development of hard X-ray / soft gamma-ray optics holds the promise of increased sensitivity by 1 to 2 orders of magnitude. Laue lenses seem to be the best technology candidate to achieve this goal. Although Laue lenses are particularly well suited for observations of faint nuclear gamma ray lines from point sources (supernovae, novae), they can be optimized for continuum sources such as hard X-ray tails from a variety of compact objects (Galactic black holes, AGNs, blazars, soft gamma-ray repeaters, etc.). We have been pursuing the technical development of Laue lenses on two fronts critical to the fabrication of a full scale lens. The first is the search for high-reflectivity and reproducible crystals. The second is the development of a fast and accurate method to mount the thousands of crystals constituting a lens. We recently produced a breadboard model of a Laue lens using a novel mounting technique and used this lens to focus an X-ray beam. Here, we report on the development status of Laue lenses, which shows that this technology will soon become mature enough to be proposed for a long duration balloon or a satellite mission.

123.09 – A Combined Compton and Coded Mask Telescope for Gamma-Ray Astrophysics

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In order to improve upon past and current observations in medium-energy gamma-ray astrophysics (Comptel, Integral/SPI), a next generation telescope must have good energy resolution to allow for accurate nuclear line shape analysis and high angular resolution to allow for resolving and locating point sources as well as diffuse emission. Additionally, a large effective area and background rejection capabilities are needed in order to achieve a high sensitivity. To address these requirements, we are investigating the potential of combining the background rejection capabilities and thus high sensitivity of a Compton telescope with the good angular resolution that can be achieved using a coded mask. We present a preliminary study of a combined telescope that utilizes an array of double-sided Silicon strip detectors as a Compton scatter plane and cubic-centimeter Cadmium Zinc Telluride (CdZnTe) semiconductor detectors as an absorption plane. The Silicon detector performance is based upon a study for the Gamma-Ray burst Investigation via Polarimetry and Spectroscopy (GRIPS) telescope. The CdZnTe detector response is based upon benchmarked laboratory measurements using 1-cm³ CdZnTe coplanar-grid detectors. The Compton telescope is combined with a partially filled coded mask with a 10° field-of-view. A series of monoenergetic line sources from 200 keV to 6.1 MeV have been simulated, as well as a 511 keV broadened source and a Crab-like continuum. The telescope has achievable energy resolutions of 1.68% FWHM at 511 keV and 1.11% at 1809 keV, on-axis angular resolutions in Compton mode of 2.63° ± FWHM at 511 keV and 1.30° ± FWHM at 1809 keV, and is capable of resolving sources to at least 0.2° using the coded mask. An initial assessment of the instrument yields an anticipated all-sky sensitivity of 3.6 x 10²⁶ photons cm⁻² s⁻¹ for a broadened 511 keV source over a 2 year observation time. These capabilities meet several scientific objectives in medium-energy gamma-ray astronomy, such as achieving the sensitivity and accuracy required for nuclear line studies and allowing for an improved assessment of the spatial distribution of Galactic 511 keV emission.

123.10 – The First Science Flight of the Gamma-Ray Polarimeter Experiment (GRAPE)

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The Gamma-Ray Polarimeter Experiment (GRAPE) is a Compton polarimeter designed to measure the polarization of astronomical sources in the soft gamma-ray band (50 - 500 keV) from a high-altitude balloon platform. Although designed primarily for studies of gamma-ray bursts over the entire sky, the instrument can also be combined with a collimator for pointed observations. The first science flight of the payload, in the collimated configuration, was launched from Ft. Sumner, NM, on September 23, 2011. Although the polarization sensitivity was limited by several factors, the instrument and payload performed well during 26 hours at float altitude, performing observations of the Crab Nebula and two M-Class solar flares. We describe the instrument, payload, science observations, and data analysis procedures, and present our upper limits for the soft gamma-ray polarization of the Crab and the solar flares. A second flight, with greatly improved sensitivity, is currently scheduled for the Fall of 2014.

123.11 – PETS - A GRB Polarimetry Mission on the International Space Station

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Polarimetry of Energetic Transients in Space (PETS) is a gamma-ray polarimetry mission that was recently proposed as an NASA Astrophysics Mission of Opportunity. It will make the first definitive observations of the inner jets of GRBs, which cannot be probed with conventional non-polarization instruments. It will also observe, for the first time, the polarization signature from SGRs, revealing high-energy emission processes originating from the most intense magnetic field conditions known to exist. PETS will use gamma-ray polarimetry to uncover the energy release mechanism associated with the formation of stellar-mass black holes and investigate the physics of extreme magnetic fields in the vicinity of compact objects. The objectives are : 1) determine the structure and composition of GRB jets and uncover the mechanisms powering them; and 2) determine the emission geometry and mechanisms under the extreme magnetic field conditions found in SGRs. The PETS science objectives are met with two instruments. The primary instrument, the TRAnsient Polarimeter (TRAP), is a wide FOV non-imaging polarimeter that measures polarization over the energy range from 50-500 keV. Knowledge of the transient source location, required for the polarization analysis, is provided by the TRAnsient Location Experiment (TRALE). PETS will be mounted on the ISS with the two instruments pointed towards the zenith, scanning the sky as it orbits the Earth. During the two-year baseline mission, PETS will achieve its primary science objective with the polarization measurement of ~100 GRBs with a minimum detectable polarization (MDP) better than 50%, ~35 GRBs with an MDP of better than 30%, and ~5 with an MDP of better than 15%. These data will be sufficient to distinguish amongst three basic models for the inner jet at a 90% confidence level. The secondary science objective will be achieved with the measurement of 3-4 SGRs with a minimum detectable polarization of 15-50%. PETS is a self-contained mission in that it will be able to achieve its objectives without relying on other sources for transient location data, while providing potentially important contextual data for other ongoing investigations. Scheduled launch date is 2018.

123.12 – Solar Particle Acceleration and The Gamma Ray Imager/Polarimeter for Solar Flares (GRIPS) Instrument

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Flares accelerate ions and relativistic electrons proportionally; the ratio of their fluences has been shown to remain constant over three orders of magnitude, a correlation that is independent of flare size. This evidence suggests that ion and electron populations are accelerated together, and possibly by similar mechanisms. In two of the best-observed flares of the last cycle, the Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI) satellite found the centroids of ion and relativistic electron associated emission to be significantly displaced from one another. This result is surprising; ions and electrons that are accelerated in the same region are thought to be transported along the same field lines, implying that they would enter the chromosphere together and have similar emission source locations. The Gamma-Ray Imager/Polarimeter for Solar Flares (GRIPS) instrument is designed to address particle transport questions by providing enhanced imaging, spectroscopy and polarimetry of gamma/HXR flare emissions (~20 keV to >>10MeV). GRIPS' key technological improvements

over the current solar state of the art in HXR/gamma ray energies (RHESSI) include the use of three dimensional germanium detectors (3D-GeDs) and a single grid modulation collimator design, the multi-pitch rotating modulator (MPRM). The 3D-GeDs allow GRIPS to Compton track energy deposition within the crystal, providing significant background reduction and solar polarization measurements. Imaging will be primarily accomplished through the MPRM grid system. The single grid design provides quasi-continuous resolution from 12.5 – 162arcsecs with 2x the throughput of a dual grid imaging system like RHESSI. This spatial resolution will be capable of imaging the separate footpoints of many flare sizes. In comparison, RHESSI images with a minimum of 35arcsecs at HXR/gamma ray energies, making the footpoints resolvable in only the largest of flares. Here, we present a discussion of GRIPS science goals, an instrument overview and recent developments in GRIPS' imaging and detector systems. GRIPS is scheduled for an engineering flight from Fort Sumner in September of this year, followed by two long duration balloon flights from Antarctica.

123.13 – Pushing the Boundaries of X-ray Grating Spectroscopy in a Suborbital Rocket

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Contributing teams: Off-Plane Grating Rocket Experiment (OGRE) Team

Developments in grating spectroscopy are paramount for meeting the soft X-ray science goals of future NASA X-ray Observatories. While developments in the laboratory setting have verified the technical feasibility of using off-plane reflection gratings to reach this goal, flight heritage is a key step in the development process toward large missions. To this end we have developed a design for a suborbital rocket payload employing an Off-Plane X-ray Grating Spectrometer. This spectrometer utilizes slumped glass Wolter-1 optics, an array of gratings, and a CCD camera. We discuss the unique capabilities of this design, the expected performance, the science return, and the perceived impact to future missions.

123.14 – The Focusing Optics X-ray Solar Imager (FOXSI): Instrument and First Flight

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Contributing teams: FOXSI Team

Understanding electron acceleration in solar flares requires hard X-ray studies with greater sensitivity and dynamic range than are available with current solar hard X-ray observers (i.e. the RHESSI spacecraft). Both these capabilities can be advanced by the use of direct focusing optics instead of the indirect Fourier methods of current and previous generations. The Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket payload demonstrates the feasibility and usefulness of hard X-ray focusing optics for solar observation. FOXSI flew for the first time on 2012 November 2, producing images and spectra of a microflare and performing a search for nonthermal X-rays from the quiet Sun. Such measurements are important for characterizing the impact of small 'nanoflares' on the solar coronal heating problem. A spaceborne solar observer featuring similar optics could make detailed observations of hard X-rays from flare-accelerated electrons, identifying and characterizing particle acceleration sites and mapping out paths of energetic electrons as they leave these sites and propagate throughout the solar corona. Solar observations from NuSTAR are also expected to be an important step in this direction.

123.15 – Latest Advancements in Microchannel Plate Detectors

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Microchannel plate (MCP) detectors have been used in space-based astronomical detectors for decades (e.g. EUVE, ROSAT, Chandra, COS on Hubble) and their performance continues to improve. We will present the latest technological developments in MCP detectors, including very large format MCPs made from low background borosilicate glass (20cm x 20cm MCPs); functionalized by atomic layer deposition of semiconductor layers and high electron emission coefficient layers which substantially increase the lifetime of the output gain; high speed cross strip readouts (> 4MHz count rate at 10% deadtime); and photocathode development for increased QE in the UV and x-ray bands. We will also present our efforts to raise the technology readiness level of our cross-strip electronics to level 6 by developing low power and low mass ASICs that can be space qualified. This work is supported by NASA Grants NNX12AF46A, NNG11AD54G and DOE grant #DE-AC02-06CH11357.

123.16 – The Science Payload of the LOFT Mission

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Contributing teams: LOFT Team

The scientific payload onboard the Large Observatory For x-ray Timing mission (LOFT, see presentation by P. Ray et al. at this meeting) is composed of two instruments, the Large Area Detector (LAD, 10 m² effective area in the primary energy range 2-30 keV, 1-deg collimated field of view) and the Wide Field Monitor (WFM, arcmin imaging over a 4-steradian field of view in the primary energy range 2-50 keV). In this paper we present the design solutions for the two experiments, together with their characteristics and anticipated scientific performance.

123.17 – The Hard X-ray Polarimeter X-Calibur - Astrophysical Motivation and Performance

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X-ray polarimetry promises to give qualitatively new information about high-energy sources, such as binary black hole systems, rotation and accretion powered neutron stars, microquasars, active galactic nuclei and gamma-ray bursts. We designed, built and tested a hard X-ray polarimeter X-Calibur to be flown in the focal plane of the InFOCuS grazing incidence hard X-ray telescope in fall 2013. The polarimeter combines a low-Z Compton scatterer with a high-Z Cadmium Zinc Telluride (CZT) detector assembly to measure the polarization of 20-80 keV X-rays. X-Calibur makes use of the fact that polarized photons Compton scatter preferentially perpendicular to the electric field orientation. In contrast to competing designs, which use only a small fraction of the incoming X-rays, X-Calibur achieves a high detection efficiency of order unity. We report on the technical design of X-Calibur, the X-Calibur and InFOCuS sensitivity on short and long duration balloon flights, and present detailed laboratory calibration measurements characterizing the performance of the instrument.

123.18 – Characterization of Si Hybrid CMOS Detectors for use in the Soft X-ray Band

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We report on the characterization of four Teledyne Imaging Systems HAWAII Hybrid Si CMOS detectors designed for X-ray detection. Three H1RG detectors were studied along with a specially configured H2RG. Hybrid CMOS detectors will be ideal for future X-ray observatories due to their fast readout speeds, high resistance to radiation and micrometeoroid damage and reduced power consumption when compared with CCDs. Read noise, interpixel capacitive crosstalk (IPC), energy resolution, and dark current were all measured for these detectors. The best read noise measurement obtained was 7.1 e- RMS. Energy resolution is reported for two X-ray lines, 1.5 & 5.9 keV, at multiple temperatures between 150 – 210 K. The best resolution measured at 5.9 keV was 250 eV (4.2 %) at 150 K, with IPC contributing significantly to this measured energy distribution. IPC upper limits of 4.0 - 5.5 % (up & down pixels) and 8.7 – 9.7 % (left & right pixels) were calculated, indicating a clear asymmetry. The H2RG, with a unique configuration designed to decrease the capacitive coupling between ROIC pixels, had an IPC of 1.8 ± 1.0 % indicating a dramatic improvement in IPC with no measurable asymmetry. Dark current measurements were in the range of 0.020 ± 0.001 - 0.280 ± 0.080 (e- sec⁻¹ pix⁻¹). We also find a consistent break in the fit to the dark current data for each detector. Above 180 K, all the data can be fit by the product of a power law in temperature and an exponential. Below 180 K the dark current decreases more slowly; a shallow power law or constant must be added to each fit, indicating a different form of dark current is dominant in this temperature regime.

123.19 – Using ACIS on the Chandra X-ray Observatory as a Particle Radiation Monitor

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The Advanced CCD Imaging Spectrometer (ACIS) is one of two focal-plane instruments on the Chandra X-ray Observatory. The CCDs are vulnerable to radiation damage, particularly by soft protons in the Earth's radiation belts and from solar storms. The primary effect of this damage is to increase the charge-transfer inefficiency (CTI) of the 8 front-illuminated CCDs and decrease scientific performance. Soon after launch, the Chandra team implemented procedures to protect ACIS and remove the detector from the telescope focus during high-radiation events: planned protection during radiation-belt transits; autonomous protection triggered by an on-board radiation monitor; and manual intervention based upon assessment of space-weather conditions. As Chandra's multilayer insulation ages, elevated temperatures have reduced the effectiveness of the on-board radiation monitor for autonomous protection. The ACIS team has developed an algorithm which uses data from the CCDs themselves to detect periods of high radiation and a flight software patch to apply this algorithm is currently active on-board the instrument. We report on the status of this flight software patch and explore the ACIS response to particle radiation through comparisons to a number of external measures of the radiation environment. We hope to better understand the efficiency of the algorithm as a function of the flux and spectrum of the particles and the time-profile of the radiation event.

123.20 – CCD Performance Evolution on Chandra and Suzaku

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The spectral performance of the Advanced CCD Imaging Spectrometer (ACIS) detectors on the Chandra X-Ray Observatory, launched in July 1999, and the X-Ray Imaging Spectrometer (XIS) detectors on the Suzaku X-Ray Satellite, launched in July 2005, continue to evolve. Operational and environmental differences are explored.

123.21 – Cross-calibration of the Instruments Onboard the Chandra, Suzaku, Swift, and XMM-Newton Observatories Using 1E 0102.2-7219: An IACHEC Study

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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, 1E0102.2-7219 (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).

123.22 – The TEST Pilot Sounding Rocket Payload

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The Transition Edge Sensor Telescope Pilot project (TEST Pilot) is a soft x-ray (0.15-2.0 keV) imaging spectrograph that is a suborbital testbed for the next generation of x-ray detectors. A simple Kirkpatrick-Baez telescope composed of flat silicon mirrors defines a 3°x3° focus and a 6°x6° field of view, while the detector array of 1,024 microcalorimeters with sub-eV resolution is the first flight demonstration of a kilopixel x-ray microcalorimeter array and of the code-domain multiplexing readout. The configuration provides an effective area of 400 cm² and a spectral resolution (R=E/ΔE) of 800 at the oxygen K lines even from extended sources -- and over 500 cm² and R=1,000 at 1 keV -- in a low-cost sounding rocket program. Scientific targets for TEST Pilot include galaxy clusters, ISM absorption lines toward the Crab nebula, solar wind charge exchange in comet tails, and historical supernova remnants or SNRs in the Large Magellanic Cloud.

123.24 – Performance of the ASTRO-H Soft X-ray Telescope (SXT-1)

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The X-ray astronomy satellite, ASTRO-H, being developed under the collaboration among JAXA, NASA's GSFC and ESA, will have two Soft X-ray Telescopes (SXTs), among other instruments onboard, with a sensitive energy band up to 15 keV. One is for an X-ray micro-calorimeter detector and the other for an X-ray CCD detector. The SXT uses a conically approximated Wolter I grazing incidence optic implemented by thin aluminum foil substrates with thickness of 0.152, 0.229, and 0.305 mm. X-ray reflecting surface is a gold thin layer (2000Å) transferred from a smooth glass mandrel to the substrate by a replication method using an epoxy buffer layer (12 μm). It is similar to the Suzaku X-ray telescope, but with larger diameter (45 cm) and longer focal length (5.6 m). Recently we have completed the first flight SXT (SXT-1). X-ray measurements with a diverging beam at the Goddard 100-m beamline found an angular resolution to be 1.13 arcmin (HPD) at 4.5 keV. Since we also found that this performance has radial dependence, the angular resolution will be different for a parallel beam, i.e. in orbit. It will be measured by the full performance characterization at ISAS/JAXA, Japan, later this year. SXT-1 has successfully gone through environmental testing (vibration and thermal) and the performance remains same. In this paper, we will report X-ray test results obtained at the Goddard X-ray beamline.

123.25 – Current Research Developments at NASA Goddard Space Flight Center on the Neutron Star Interior Composition Explorer (NICER) X-ray Concentrators

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NICER is a proposed NASA Explorer Mission of Opportunity and will study the extreme gravitational, electromagnetic, and nuclear physics of neutron stars. Observations will be performed by an X-ray timing and spectroscopy instrument on board the International Space Station (ISS) with launch scheduled for late 2016. NICER consists of grazing incident optics coupled with silicon drift detectors that will provide high throughput photon collection with relatively low background. The optical system consists of 56 X-ray optics, each of which comprise of 24 individual concentrators made from thin aluminum shells with epoxy replicated gold surface. These specialized concentrators focus incident X-rays allowing for small detectors thus increasing the signal to noise while minimizing mass and fabrication cost. The concentrators have three distinct design differences from traditional thin foil epoxy replicated imaging optics. Firstly, the concentrators use only a single reflection and therefore have degraded imaging resolution for extended sources. They also have a full shell structure to further improve the effective area to mass ratio and a curved axial profile to improve resolution and hence concentration at a short focal length. NICER is the second project using these style concentrators, the first of which was the X-ray Advanced Concepts Testbed (XACT) sounding rocket payload (expected to launch in December 2013). The fabrication of the NICER optics began in spring 2012 and were tested using a collimated X-ray beam in summer 2012. In the following months, the concentrators' fabrication method has been improved and adapted from the method used with XACT. X-ray measurements have been made to characterize the concentrators by calculating half power diameters, off-axis performance, and effective area measurements. These have been compared to ray tracing and theoretical calculations. Here we report the performance to date with comparisons to the theoretical calculations as well as the advancements in the fabrication method from the previous generation X-ray concentrators.

123.26 – A Future Generation High Angular Resolution X-ray Telescope Based Upon Physical Optics

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Although the highest priority objective for the next major X-ray mission is high resolution spectroscopy we will ultimately want the next generation high angular resolution X-ray observatory. This author believes that the 0.5 arc second angular resolution of the Chandra X-Ray Observatory is likely to be close to the best that can be obtained with grazing incidence optics, especially with larger effective area. Telescopes based upon physical optics, diffraction and refraction that transmit rather than reflect X-rays can have an angular resolution of a milli arc second or better. Combining the diffractive and refractive components into one unit can neutralize the chromatic aberration of each individually over a ~15% bandwidth at 6 keV. The aperture could be divided into several diffractive-refractive pairs to broaden the bandwidth. Furthermore these telescopes would be very low cost, very light weight, and more tolerant of figure errors and surface roughness than grazing incidence telescopes. However, focal lengths are of the order of 1000 km, which requires a new mission architecture consisting of long distance formation-flying between two spacecraft, one hosting the optics, the other, the detector. One of the spacecraft requires propulsion, provided by, for example, ion engines to maintain the optics-detector alignment by counteracting gravity gradient forces, and for changing targets. Although their effective area can be large and their angular resolution very high diffractive-refractive telescopes are not necessarily more sensitive than Chandra because their large focal plane scale (1 milli arc second ~ 1 mm) subjects them to a higher level of cosmic ray background and their opacity results in a lower energy limit of 2 keV. The intrinsic field of view is wide but the large focal length scale and practical limits on the size of the detector array results in a small field of view.

123.27 – Next Generation X-ray Optics: High Angular Resolution, Light Weight, and Low Production Cost

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X-ray optics is an essential enabling component of nearly every future x-ray astronomical mission concept. In this poster we will present the rationale, technical approach, and status of an x-ray optics technology development program that has been underway at Goddard Space Flight Center and Marshall Space Flight Center.

123.28 – The Development of Adjustable X-ray Optics: Status and Plans

Paul B. Reid¹, Thomas L. Aldcroft¹, Vincenzo Cotroneo¹, William Davis¹, Raegan L. Johnson-Wilke², Stuart McMuldroy¹, Brian Ramsey³, Daniel A. Schwartz¹, Susan Trolrier-McKinstry³, Alexey Vikhlinin¹, Rudeger Wilke³

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We report on the continuing development of adjustable, grazing incidence X-ray optics. Adjustable X-ray optics offer the potential for achieving sub-arcsecond imaging resolution while sufficiently thin and light-weight to constitute a mirror assembly with several square meters collecting area. The adjustable mirror concept employs a continuous thin film of piezoelectric material deposited on the back of the paraboloid and hyperboloid mirror segments. Individually addressable electrodes on the piezo layer allow the introduction of deformations in localized 'cells' which are used to correct mirror figure errors resulting from fabrication, mounting and aligning the thin mirrors, residual gravity release and temperature changes. We describe recent results of this development. These include improving piezo cell yield to ~ 100 per cent for cm² cells, measurements of hysteresis and stability, comparisons of modeled and measured behavior, simulations of mirror performance, and the development and testing of the first cylindrical (i.e., non-flat) test mirrors. We also present our plans going forward toward the eventual goal of achieving TRL 6 prior to the 2020 Decadal Review.

123.29 – SMART-X: Square Meter, Arcsecond Resolution Telescope for X-rays

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Contributing teams: SMART-X Collaboration

SMART-X is a concept for a next-generation X-ray observatory with large-area, 0.5' angular resolution grazing incidence adjustable X-ray mirrors, high-throughput critical angle transmission gratings, and X-ray microcalorimeter and CMOS-based imager in the focal plane. High angular resolution is enabled by new technology based on controlling the shape of mirror segments using thin film piezo actuators deposited on the back surface. Science applications include observations of growth of supermassive black holes since redshifts of ~10, ultra-deep surveys over 10's of square degrees, galaxy assembly at z=2-3, as well as new opportunities in the high-resolution X-ray spectroscopy and time domains. We also review the progress in technology development, tests, and mission design over the past year.

123.30 – Comparing Wolter I and Wolter-Schwarzschild I Sensitivity for the SMART-X Telescope

Daniel A. Schwartz¹, Tom Aldcroft¹, Jay A. Bookbinder¹, Vincenzo Cotroneo¹, Bill Forman¹, Terry Gaetz¹, Diab H. Jerius¹, Stuart McMuldroy¹, Paul B. Reid¹, Harvey Tananbaum¹, Alexey Vikhlinin¹

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For a representative SMART-X telescope prescription with 2.3 m² effective area at 1 keV, we estimate off-axis resolution, number of resolution elements, number of background counts per resolution element in a 1 Ms observation, and the number of counts (and flux) required to give a 3 sigma or 5 sigma significance detection in that 1 Ms observation. These are compared for an ideal Wolter I (W I) and an ideal Wolter-Schwarzschild I (W-S I) prescription, convolved with a 0.5 arcsecond half-power diameter (HPD) resolution on-axis. The W-S design is more than twice as sensitive beyond 4 arcmin off-axis. With the piezoelectric figure adjustment to be used on SMART-X, we believe either design can be achieved.

123.31 – The ASTRI Project: An Innovative Prototype for a Cherenkov Dual-mirror Small-telescope

Stefano Vercellone¹, Osvaldo Catalano¹, Maria Concetta Maccarone¹, Rodolfo Canestrari², Giovanni Pareschi², Federico Di Pierro³, Piero Vallania³, Patrizia Caraveo⁴, Gino Tosti⁵

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Contributing teams: ASTRI Collaboration

ASTRI ("Astrofisica con Specchi a Tecnologia Replicante Italiana") is a flagship project of the Italian Ministry of Education, University and Research. Within this framework, INAF is currently developing a wide field of view (9.6 degrees in diameter) end-to-end prototype of the CTA small-size telescope (SST), devoted to the investigation of the energy range from a fraction of TeV up to tens of TeV. For the first time, a dual-mirror (2M) Schwarzschild-Couder optical design will be adopted on a Cherenkov telescope, in order to obtain a compact (F# = 0.5) optical configuration. A second challenging, but innovative technical solution consists of a focal plane camera based on Silicon photo-multipliers with a logical pixel size of 0.17 degrees (6.2mm x 6.2mm). The ASTRI SST-2M prototype will be placed at Serra La Nave, 1735 m a.s.l. on the Etna Mountain near Catania, Italy, at the INAF 'M.G. Fracastoro' observing station, and data acquisition is scheduled to start in 2014. Although the ASTRI SST-2M prototype is mainly a technological demonstrator, it will perform scientific observations on the Crab Nebula, Mrk 421 and Mrk 501. We will describe the current status of the project, its performance, and its synergies with other CTA SSTs projects.

123.32 – The ASTRI Mini-Array Science Case

Stefano Vercellone¹, Osvaldo Catalano¹, Maria Concetta Maccarone¹, Antonio Stamerra², Federico Di Pierro², Piero Vallania², Rodolfo Canestrari³, Giacomo Bonnoli³, Giovanni Pareschi³, Gino Tosti⁴, Patrizia Caraveo⁵

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Contributing teams: ASTRI Collaboration

ASTRI is a flagship project of the Italian Ministry of Education, University and Research. Within this framework, INAF is currently developing an end-to-end prototype of the CTA small-size telescope in a dual-mirror configuration (SST-2M) to be tested under field conditions, and scheduled to start data acquisition in 2014. A remarkable improvement in terms of performance could come from the operation, in 2016, of a SST-2M mini-array, composed by a few SST-2M telescopes and to be placed at final CTA Southern Site. The SST mini-array will be able to study in great detail relatively bright sources (a few $\times 10^{12}$ erg/cm²/s at 10 TeV) with an angular resolution of a few arcmin and an energy resolution of about 10 – 15%. Moreover, thanks to the array approach, it will be possible to verify the wide FoV performance to detect very high energy showers with the core located at a distance up to 500 m, to compare the mini-array performance with the Monte Carlo expectations by means of deep observations of few selected targets, and to perform the first CTA science, with its first solid detections during the first year of operation. Prominent sources such as extreme blazars (1ES 0229+200), nearby well-known BL Lac objects (MKN 501) and radio-galaxies, galactic pulsar wind nebulae (Crab Nebula, Vela-X), supernovae remnants (Vela-junior, RX J1713.7-3946) and microquasars (LS 5039), as well as the Galactic Center can be observed in a previously unexplored energy range, in order to investigate the electron acceleration and cooling, relativistic and non relativistic shocks, the search for cosmic-ray (CR) Pevatrons, the study of the CR propagation, and the impact of the extragalactic background light on the spectra of the sources.

123.33 – Results and Highlights from the Pierre Auger Observatory

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Contributing teams: Pierre Auger Collaboration

Ultra-high energy cosmic rays are the most energetic particles in the universe but properties such as their composition and sources are poorly understood. The extremely low flux of these particles, less than 1 particle km⁻² yr⁻¹ above 10^{18} eV, necessitates indirect detection methods using the extensive air showers initiated when the cosmic ray interacts within the atmosphere. Located in the high pampa of Argentina, the Pierre Auger Observatory is the largest cosmic ray detector in the world and combines two traditional air shower detection techniques: air fluorescence telescopes and water Cherenkov ground-based detectors. These allow precision measurements of the energy spectrum and the arrival directions, as well as data to infer the chemical composition of the cosmic ray primaries. I will highlight recent results from the Observatory within the last year including the energy spectrum, arrival direction anisotropies, composition studies, and particle interaction cross-section measurements.

124 – SMBH, GRB

124.01 – Some Implications of Correlated GRB Pulse Properties

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Many observed GRB pulses and flare properties are strongly correlated, including duration, lag, peak and bolometric flux and luminosity, and asymmetry. Correlations occur across all GRB classes, in the prompt emission and afterglow, and across many spectral regimes, suggesting that the pulse emission mechanism is ubiquitous and relatively simple. In addition to constraining many theoretical GRB models, we show that pulse structure is indicative of a simple energy decay process. The fact that different GRB instruments observe similar correlated pulse properties suggests that the pulse rise and peak flux are more of symptom of the process than its climax.

124.02 – Radiation from Accelerated Particles in Relativistic Jets with Shocks, Shear-flow, and Reconnection

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We investigated particle acceleration and shock structure associated with an unmagnetized relativistic jet propagating into an unmagnetized plasma. Strong magnetic fields generated in the trailing shock contribute to the electron's transverse deflection and acceleration. We have calculated, self-consistently, the radiation from electrons accelerated in these turbulent magnetic fields. We found that the synthetic spectra depend on the bulk Lorentz factor of the jet, its temperature and strength of the generated magnetic fields. We also investigate synthetic spectra from accelerated electrons in strong magnetic fields generated by kinetic shear (Kelvin-Helmholtz) instabilities. The calculated properties of the emerging radiation provide our understanding of the complex time evolution and/or spectral structure in gamma-ray bursts, relativistic jets in general, and supernova remnants.

124.03 – GRB Flares: A New Detection Algorithm, Previously Undetected Flares, and Implications on GRB Physics

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Flares in GRB light curves have been observed since shortly after the discovery of the first GRB afterglow. However, it was not until the launch of the Swift satellite that it was realized how common flares are, appearing in nearly 50% of all X-ray afterglows as observed by the XRT instrument. The majority of these observed X-ray flares are easily distinguishable by eye and have been measured to have up to as much fluence as the original prompt emission. Through studying large numbers of these X-ray flares it has been determined that they likely result from a distinct emission source different than that powering the GRB afterglow. These findings could be confirmed if similar results were found using flares in other energy ranges. However, until now, the UVOT instrument on Swift seemed to have observed far fewer flares in the uv/optical than were seen in the X-ray. This was primarily due to poor sampling and data being spread across multiple filters, but a new optimal co-addition and normalization of the UVOT data has allowed us to search for flares in the uv/optical that have previously gone undetected. Using a flare finding algorithm based on the Bayesian Information Criterion, we have analyzed the light curves in the Second UVOT GRB Catalog and present the finding of at least 118 unique flares detected in 68 GRB afterglows. We have also analyzed the XRT observed afterglows from the same time period using the flare finding algorithm, in an attempt to find smaller, previously unreported X-ray flares. Here we report our initial findings of this analysis on the X-ray afterglows and the number of flares detected. The cross-correlation of these two flare catalogs will better constrain the precise origin of flares, and also lead to a better understanding of the nature of the central engine, one of the likely origin candidates.

124.05 – Could High-energy Gamma-ray Photon Emission be Associated to External Shocks?

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Delayed photons with energies greater than 100 MeV have been detected in a few gamma-ray bursts (GRBs). The emission of these photons can be either, of longer or shorter duration than duration of the prompt emission. We propose that long- and short- lasting emissions can be understood as synchrotron self-Compton (SSC) emission in the thick case from the reverse and forward external shocks, respectively, when the jet is magnetized. We have tested the model in several bursts as GRB090926 and GRB980923 and found fluxes, energies and durations of the emissions consistent with the observations. We have found that the presence of a short-duration high-energy emission can be interpreted as a consequence of magnetized jet, while the longer duration emission may be an indication of the external environment density. Here, we present the model and results for several bursts.

124.06 – High-Energy Neutrino Oscillation in Hidden Jets from GRBs

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High-energy neutrinos and photons can be produced inside the middle relativistic jets in the core-collapse supernova. Although photons can hardly escape, high energy neutrinos could be the only signature in optically thick hidden. Due to matter effects, high energy neutrinos may oscillate resonantly from one flavor to other before leaving the star. Using the two and three neutrino mixing, we study the possibility of resonant oscillation as function of energy and distance and calculate the oscillation probability from each flavor to another. We compute the flavor ratio expected on Earth.

124.07 – Propagation and Neutrino Oscillations in the Base of a Highly Magnetized Gamma-ray Burst Fireball Flow

Nissim I. Fraija¹

1. IA-UNAM, Mexico D.F., Mexico.

We derive the neutrino self-energy and the effective potential up to order $1/M_W^4$ in a highly magnetized gamma-ray burst fireball flow which is made up of electrons, protons, neutrons and their anti-particles. We consider neutrinos of energies of about 1-30 MeV which are produced due to stellar collapse, merger events or in the fireball itself. Electron-positron annihilation, inverse beta decay and nucleonic bremsstrahlung bring about thermal neutrino inside of Fireball. Many of these neutrinos will propagate through of it and may oscillate resonantly. Using the two and three neutrino mixing, we study the possibility of resonant

oscillation and based of this we estimate the observables of the fireball like lepton asymmetry as well as baryon load.

125 – Solar and Stellar

125.01 – Constraints on Porosity and Mass Loss in O-star Winds from Modeling of X-ray Emission Line Profile Shapes

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Spectrally resolved X-ray line shapes in massive stars provide important diagnostics of X-ray production mechanisms and they have also, surprisingly, been used to make some of the most accurate and model-independent wind mass-loss rate estimates. Measurements of several nearby O stars using the grating spectrometers onboard *Chandra* and XMM-*Newton* have revised downward the mass-loss rates of O stars, with implications for stellar evolution and the energy budget in clusters. But if these winds are porous, then the X-ray mass-loss rates might be subject to systematic underestimates. Here we present a formalism for modeling the effects of wind porosity on X-ray emission line profiles, and fit these models to *Chandra* and XMM observations of ζ Pup. We find that strong porosity effects are ruled out, and for moderate porosity we quantify the degeneracy between assumed porosity length and derived mass-loss rate. We conclude that mass-loss rates derived from fitting X-ray line profiles assuming no porosity effects are overestimated by at most 50% if moderate porosity effects are indeed important.

125.02 – New Line Identifications in the Spectrum of Procyon Observed with the Chandra X-ray Observatory

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We have analyzed 280 ks of co-added observations performed with *Chandra*'s Low Energy Transmission Grating Spectrometer using theoretical spectra of Fe VIII through Fe XVII. The model spectral data were produced by combining collisional excitation data generated with the Flexible Atomic Code and transition energies generated with a relativistic code based on the multi-reference Møller-Plesset perturbation theory. The spectroscopic accuracy of the theoretical Fe IX wavelengths was ascertained in a comparison with existing laboratory measurements. We find five new Fe IX lines in the 100–140 Å region and confirm two previous identifications. We also have identified one new line from Fe X near 111 Å. Two lines near 104 and 106 Å, respectively, have been assigned to Fe XIII, and a line near 100.5 Å has been identified as an Fe XI line. The Fe IX emission is weakly sensitive to the assumed electron density, while the Fe XIII is strongly dependent on density. We find that a density between 10^9 and 10^{10} cm⁻³ provides the best fit to the Procyon spectrum. In addition, we confirmed the presence of two out of four Fe VIII lines that were thought to exist in the spectrum. These two lines are located near 131 Å. We note that several of the new identifications have come at the expense of prior assignments to magnesium or calcium lines, removing evidence for the presence of these elements. Work by the Lawrence Livermore National Laboratory was performed under the auspices of the Department of Energy under Contract No. DE-AC52-07NA-27344. This work was supported by *Chandra* Guest Observer Award GO0-11031X.

126 – Stellar Compact

126.01 – Mass Ejection in Novae as Traced by the Karl G. Jansky Very Large Array

Laura Chomiuk^{1, 2}, Thomas Nelson³, Koji Mukai^{4, 5}, Jennifer L. Sokoloski⁶, Michael P. Rupen², Jennifer Weston⁶, Yong Zheng⁶, Amy J. Mioduszewski², Nirupam Roy², Miriam I. Krauss²

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We present radio light curves, spectra, and images for several recent novae, including the gamma-ray novae Mon 2012 and Sco 2012 and the recurrent nova T Pyx. Radio observations of novae simply trace the bulk of the ejected mass via thermal free-free emission, revealing surprisingly complex mass ejection histories and accurate estimates of the ejecta mass.

126.02 – The E-Nova Project: Insights from X-ray Observations

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Classical and recurrent novae are often seen to emit optically thin X-ray emissions in the 1-10 keV range, 1 week to several years after optical peak. We present selected results from Swift and Suzaku observations of recent novae obtained as part of the E-Nova project (see Nelson et al.) as well as archival data. The very presence of such X-rays show that collisions between multiple systems of ejecta, at relative velocities of $>1,000$ km/s, are common in classical novae. The fact that some of these shocks are also capable of particle acceleration has been demonstrated by the recent Fermi detection of 3 novae. We will present the temperature and luminosity evolution of shock X-ray emission in several novae. We can put some constraints on the cooling time of the shocked ejecta; we will consider the implications on the density of ejecta. Furthermore, we commonly observe intrinsic absorption that decreases with time. We interpret this as due to expansion of the unshocked part of the outer ejecta. We will use this, in conjunction with radio data (see Chomiuk et al.), to infer the often complex history of mass ejection in classical and recurrent novae.

126.03 – The Effect of Micro-lensing in Eclipsing Binary-star Systems

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Using photometric observations from the Kepler Space Telescope of eclipsing binary star systems where one component is a white dwarf we have investigated the strength of the micro-lensing effect. We have examined the stellar binary KOI-81 from the Kepler mission. KOI-81 is composed of a white dwarf and a A-type main-sequence star in a 24 day circular orbit and have found that micro-lensing is detectable. We use our lightcurve models to measure the strength of the micro-lensing signal and refine the radius of the eclipsing white dwarf.

126.04 – Characterization of New Hard X-ray Cataclysmic Variables

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Magnetic cataclysmic variables (mCVs) constitute a subgroup of the CV class: close binary systems in which a white dwarf (the primary) accretes from a Roche-lobe filling main-sequence mass donor (the secondary) and consequently emits in the X-ray. mCVs host an accreting white dwarfs (WD) with magnetic field strengths $B \geq 10^5$ G. These systems are further subdivided in two groups, depending on the WD magnetic field intensity and degree of synchronism ($P_{\text{rot}} = P_{\text{orb}} = ?$). Those called Polars are synchronous mCVs showing signatures of strong magnetic fields ($B \geq 10^2$ – 230 MG). The so-called intermediate polars (IPs) possess instead asynchronously rotating WDs ($P \ll P_{\text{rot}}$) and weakly magnetized WDs ($B < 10$ MG). Though mCVs represent a relatively small ($\sim 20\%$) fraction of CVs, this number is rapidly increasing thanks to the recent hard X-ray surveys conducted by INTEGRAL and Swift above 20 keV. Hard X-ray mCVs (IPs) have the potential to be important contributors to the X-ray source population at low luminosities ($\sim 10^{30}$ – 10^{33} erg s^{-1}). They were proposed to be the major constituent of galactic ridge and galactic bulge X-ray emission. Therefore, they are also believed to have an important role in the X-ray luminosity function of other galaxies. We performed an X-ray follow-up campaign of a sample of new hard CV candidates detected above 20 keV, aimed at characterizing their timing (spin period and orbital period) and spectral properties. Most of the sources are identified as IPs with spin-to-orbit period ratios of the order of 0.1. Spectral analysis reveals multiple components and complex absorptions from both cool and warm absorbing material. We discuss the results of their hard X-ray properties in terms of compact star masses. We also discuss in more detail the most interesting and peculiar cases.

126.07 – Exploring Radio and Gamma-ray Emission Models Using Millisecond Pulsars in the Second LAT Pulsar Catalog

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With three years of sky-survey data from the Fermi LAT, significant gamma-ray pulsations have been detected from ~ 40 millisecond pulsars (MSPs) using radio timing solutions from across the globe. We have fit the radio and gamma-ray pulse profiles of these MSPs using geometric emission models assuming a vacuum, retarded-dipole magnetosphere. The best-fit parameters provide constraints on the viewing geometries and emission sites. Fitting a large sample of

MSPs allows us to average over uncertainties associated with the vacuum field assumption and look for significant trends in the population. We will review the emission models, discuss implications from the fits, and speculate on paths forward to a better understanding of high-energy pulsar emission. Portions of this research performed at NRL are sponsored by NASA DPR S-15633-Y.

126.08 – Pulsar Astrophysics at Very High Energies in the Fermi-HAWC Era

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Pulsar astrophysics has received a major boost in recent years with the tremendous progress achieved in the gamma-ray regime. In the 0.1-100 GeV energy range, where pulsars emit a large fraction of their energy, the Fermi Large Area Telescope (LAT) is providing an abundance of high-quality data, greatly improving our understanding of the pulsar mechanism. In addition to detecting over 120 pulsars, the improved statistics from the LAT have enabled studies of some of the brightest pulsars with exquisite detail, up to unprecedented energies (in some cases above 25 GeV), finally bridging the gap with ground-based instruments. At very high energies (VHE, > 100 GeV), recent detections by VERITAS and MAGIC of pulsations from the Crab pose a serious challenge to pulsar models. It is unclear whether the Crab is unique in this respect, or whether VHE emission is common in other pulsars. Some models predict that such emission should smoothly connect with the standard GeV emission seen by the LAT, while others point instead to a different spectral (e.g. inverse Compton) component altogether. If present in other pulsars, such a component might be found at higher energies (> 1 TeV), but its flux is highly uncertain. Further VHE observations of pulsars are crucial to distinguish between (and constrain) the competing scenarios. The High Altitude Water Cherenkov Observatory (HAWC), currently under construction in Mexico, is well-suited to perform observations of pulsars above 100 GeV. The HAWC detector has a wide field of view, high duty cycle, and excellent sensitivity (~15 times better than its predecessor Milagro), and its contemporaneous operation with Fermi should enable it to carry out the first comprehensive survey of northern-hemisphere gamma-ray pulsars above 100 GeV. I will discuss the motivations, goals, timeline, and sensitivity of HAWC searches for VHE emission from pulsars.

126.09 – Hard X-ray Emission by Resonant Compton Upscattering in Magnetars

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Flat spectrum, non-thermal X-ray quiescent emission extending between 10 keV and around 150 keV has been seen in a number of magnetars by RXTE, INTEGRAL, Suzaku and Fermi-GBM. For inner magnetospheric models of such hard X-ray emission, resonant Compton upscattering is anticipated to be the most efficient process for generating continuum radiation. This is because the scattering becomes resonant at the cyclotron frequency, and the effective cross section exceeds the classical Thomson value by over two orders of magnitude, thereby enhancing the efficiency of continuum production and the cooling of relativistic electrons. We present angle-dependent hard X-ray upscattering model spectra for uncooled monoenergetic relativistic electrons injected in inner regions of pulsar magnetospheres. These spectra are integrated over closed field lines and obtained for different observing perspectives. The spectral cut-off energies are critically dependent on the observer viewing angles and electron Lorentz factor. We find that electrons with energies less than around 15 MeV will emit most of their radiation below 250 keV, consistent with the observed turnovers in magnetar hard X-ray tails. Moreover, electrons of higher energy still emit most of the radiation below 1 MeV, except for very select viewing perspectives that sample tangents to field lines, thereby making it difficult to observe signals extending into the Fermi-LAT band. Our spectral computations use, for the first time, a new Sokolov and Temov (ST) formulation of the QED Compton scattering cross section in strong magnetic fields. Such an ST formalism is formally correct for treating spin-dependent effects that are important in the cyclotron resonance.

126.10 – On the X-ray Variability of Magnetar 1RXS J170849.0-400910

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The magnetar 1RXS J170849.0-400910 displayed several glitches during the period between 1999 and 2006. Previous studies have claimed variations of ~50% in the soft X-ray flux that accompanied some of the glitches. Here we report on a reanalysis of the Chandra, XMM, and Swift data spanning the epoch of the claimed variability. We find no evidence of flux and spectral variations at the level claimed in previous studies. We summarize the radiative properties of magnetar glitches and discuss their implications.

126.12 – The Correlation Between Dispersion Measure and X-ray Column Density from Radio Pulsars

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Pulsars are remarkable objects that emit across the entire electromagnetic spectrum, providing a powerful probe of the interstellar medium. In this study, we investigate the relation between dispersion measure (DM) and X-ray absorption column density NH using 68 radio pulsars detected at X-ray energies with the Chandra X-ray Observatory or XMM-Newton. We find a best-fit empirical linear relation of $NH (10^{20} \text{ cm}^{-2}) = 0.30 + 0.13 - 0.09 \text{ DM (pc cm}^{-3}\text{)}$, which corresponds to an average ionization of $10^{+4-3}\%$, confirming the ratio of one free electron per ten neutral hydrogen atoms commonly assumed in the literature. We also compare different NH estimates and note that some NH values obtained from X-ray observations are higher than the total Galactic HI column density along the same line of sight, while the optical extinction generally gives the best NH predictions.

126.13 – Magnetic Pair Creation Transparency in Pulsars

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The Fermi gamma-ray pulsar database now exceeds 115 sources and has defined an important part of Fermi's science legacy, providing rich information for the interpretation of young energetic pulsars and old millisecond pulsars. Among the well established population characteristics is the common occurrence of exponential turnovers in the 1-10 GeV range. These turnovers are too gradual to arise from magnetic pair creation in the strong magnetic fields of pulsar inner magnetospheres, so their energy can be used to provide lower bounds to the typical altitude of GeV band emission. We explore such constraints due to single-photon pair creation transparency below the turnover energy. We adopt a semi-analytic approach, spanning both domains when general relativistic influences are important and locales where flat spacetime photon propagation is modified by rotational aberration effects. Our work clearly demonstrates that including near-threshold physics in the pair creation rate is essential to deriving accurate attenuation lengths. The altitude bounds, typically in the range of 2-6 neutron star radii, provide key information on the emission altitude in radio quiet pulsars that do not possess double-peaked pulse profiles. For the Crab pulsar, which emits pulsed radiation up to energies of 120 GeV, we obtain a lower bound of around 15 neutron star radii to its emission altitude.

126.14 – Compton Scattering Cross Sections in Strong Magnetic Fields: Advances for Neutron Star Applications

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Various telescopes including RXTE, INTEGRAL and Suzaku have detected non-thermal X-ray emission in the 10 – 200 keV band from strongly magnetic neutron stars. Inverse Compton scattering, a quantum-electrodynamical process, is believed to be a leading candidate for the production of this intense X-ray radiation. Magnetospheric conditions are such that electrons may well possess ultra-relativistic energies, which lead to attractive simplifications of the cross section. We have recently addressed such a case by developing compact analytic expressions using correct spin-dependent widths and Sokolov & Temov (ST) basis states, focusing specifically on ground state-to-ground state scattering. However, inverse Compton scattering can cool electrons down to mildly-relativistic energies, necessitating the development of a more general case where the incoming photons acquire nonzero incident angles relative to the field in the rest frame of the electron, and the intermediate state can be excited to arbitrary Landau levels. In this paper, we develop results pertaining to this general case using ST formalism, and treating the plethora of harmonic resonances associated with various cyclotron transitions between Landau states. Four possible scattering modes (parallel-parallel, perpendicular-perpendicular, parallel-perpendicular, and perpendicular-parallel) encapsulate the polarization dependence of the cross section. We present preliminary analytic and numerical investigations of the magnitude of the extra Landau state contributions to obtain the full cross section, and compare these new analytic developments with the spin-averaged cross sections, which we develop in parallel. Results will find application to various neutron star problems, including computation of Eddington luminosities in the magnetospheres of magnetars. We express our gratitude for the generous support of the Michigan Space Grant Consortium, of the National Science Foundation (REU and RUI), and the NASA Astrophysics Theory and Fundamental Program.

126.15 – A Complete Set of Timing Solutions for all Three Anti-Magnetars

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We have finally obtained phase-connected coherent timing solutions for all three known pulsars in the class of Central Compact Objects (CCOs) in supernova remnants. These measurements now fully confirm that these young neutron stars have exceptionally weak dipole magnetic field components. Our latest timing campaign of the 424 ms 1E 1207.4-5209 resolves the previous ambiguities about its spin-down rate and results in a $\dot{P} = (2.22 \pm 0.02) \times 10^{-17}$, corresponding to dipole field of $B_s = 9.8 \times 10^8$ G. This is compatible with a cyclotron resonance interpretation of its prominent absorption line at 0.7 keV and harmonics. We also present results for the 112 ms PSR J0821-4300 in Puppis A. Its proper motion, $\mu = 61 \pm 9$ mas/yr, measured using Chandra, contributes a kinematic term to the period derivative via the Shklovskii effect, which is subtracted from \dot{P} to derive $B_s = 2.9 \times 10^8$ G, a value similar to that of first measured CCO PSR J1852+0040 in Kes 79, which has $B_s = 3.1 \times 10^8$ G. Applying the antipodal model to the X-ray spectrum and pulse profiles of PSR J0821-4300, we deduce the surface hot and warm spot temperatures and areas. Paradoxically, such nonuniform surface temperature appears to require strong crustal magnetic fields, probably toroidal or quadrupolar components much stronger than the external dipole. A spectral feature, consisting of either an emission line at approx. 0.75 keV or absorption at approx. 0.46 keV, is modulated in strength with the rotation. It may be due to a cyclotron process in a magnetic field on the surface that is slightly stronger than the dipole deduced from the spin-down. These results deepen the mystery of the origin and evolution of CCOs: why are their numerous descendants not evident?

126.16 – Population Synthesis of Radio and X-ray Normal, Isolated Pulsars Using Markov Chain Monte Carlo

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We present preliminary results of a population statistics study of normal pulsars (NP) from the Galactic disk using Markov Chain Monte Carlo techniques optimized according to two different methods. The first method compares the detected and simulated cumulative distributions of series of pulsar characteristics, varying the model parameters to maximize the overall agreement. The advantage of this method is that the distributions do not have to be binned. The other method varies the model parameters to maximize the log of the maximum likelihood obtained from the comparisons of four-dimensional distributions of radio and X-ray pulsar characteristics. The advantage of this method is that it provides a confidence region of the model parameter space. The computer code simulates neutron stars at birth using Monte Carlo procedures and evolves them to the present assuming initial spatial, kick velocity, magnetic field, and period distributions. Pulsars are spun down to the present and given radio and X-ray emission characteristics, implementing an empirical X-ray luminosity model. A comparison group of radio NPs detected in ten-radio surveys is used to normalize the simulation, adjusting the model radio luminosity to match a birth rate. We include the Fermi pulsars in the forthcoming second pulsar catalog. We present preliminary results comparing the simulated and detected distributions of radio and X-ray NPs along with a confidence region in the parameter space of the assumed models. We express our gratitude for the generous support of the National Science Foundation (REU and RUI), Fermi Guest Investigator Program and the NASA Astrophysics Theory and Fundamental Program.

126.17 – Population Synthesis of Radio and X-ray Millisecond Pulsars Using Markov Chain Monte Carlo

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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 X-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 ten radio surveys and by Fermi, predicting the MSP birth rate in the Galaxy. We follow a similar set of assumptions that we have used in previous, more constrained Monte Carlo simulations. The parameters associated with the birth distributions such as those for the accretion rate, magnetic field and period distributions are also free to vary. With the large set of free parameters, we employ Markov Chain Monte Carlo simulations to explore the large and small worlds of the parameter space. We present preliminary comparisons of the simulated and detected distributions of radio and X-ray pulsar characteristics. We express our gratitude for the generous support of the National Science Foundation (REU and RUI), Fermi Guest Investigator Program and the NASA Astrophysics Theory and Fundamental Program.

126.18 – A Multi-wavelength Campaign to Study Crab Giant Pulses

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We have carried out a monitoring campaign with NASA 70-m antennas to capture a large sample of Crab Giant Pulses (CGP) at multiple radio wavelengths. The goal of this campaign has been to carry out a correlation study of CGPs at radio frequencies with pulsed emission from the Crab pulsar with Fermi gamma-

ray photons. After the first year of this study, we expect around 200 Fermi photons to coincide with a CGP radio-frequency detection, allowing us to either confirm a predicted correlation in average gamma-ray pulsed flux increase with GP emission, or place a tight upper limit, at least a factor of 10 more constraining than previous work. We will report on the status of our campaign over the past year with our preliminary results. We will also report on the prospects for future improvements in receivers and back-end instrumentation to capture a larger population of GPs.

126.19 – Suzaku Observations of Orbital Phase-Dependent Dipping and Obscuration in Cyg X-1

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The black hole candidate Cygnus X-1 is in orbit around O9.7Iab companion which has a significant wind component that intersects our line of sight to the X-ray source. At superior conjunction (orbital phase 0, i.e., the O-star companion in front of the black hole), strong absorption lines of hydrogen-like and helium-like ions are clearly detected, as we have shown with prior high-resolution X-ray spectroscopy observations utilizing Chandra-HETG and XMM-Newton RGS. But along with a highly ionized component, the wind contains colder, denser clumps of material which lead to deep dipping periods at soft X-ray. Such dips have been seen and characterized with lower resolution X-ray instruments as well. These dense clumps appear over all orbital phases, although they are most prevalent near phase 0, and least prevalent near phase 0.5. In this poster, we show how the ionized wind and dense clumps manifest themselves in the CCD-quality spectra obtained with Suzaku. Suzaku has a combination of large effective area, moderate spectral resolution, and a spectral response extending to energies as low as 500 eV. The presence of the ionized wind is clearly required in the Suzaku spectra, even outside of dipping periods, and we describe how we model it in the CCD spectra. Additionally, we describe the dipping behavior as a function of orbital phase. Some of the Suzaku observations have one of the CCDs run in high time resolution mode, which allows us to characterize the temporal profile of the dips. Some of the dips can be extremely deep over remarkably short time scales, leading one to describe the average spectra with 'partial covering models' wherein the partial covering may be better described as being temporal rather than spatial. This research is supported by NASA Grant ADP_2011_NNX12AE37G.

126.20 – Influence of Non-geodesic Effects on Black Hole Spin Estimations Obtained from QPO Models

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One of the popular ways for obtaining estimations of black hole spin is a method related to models for high-frequency quasi-periodic oscillations (QPOs). In the past, estimations for three microquasars GRS 1915+105, GRO J1655-40, and XTE J1550-564 were carried out based on several QPO models assuming a geodesic accretion flow. In this work we assume a non-geodesic accretion flow described by the model of a pressure-supported perfect fluid torus and explore the influence of the pressure forces on the spin predictions calculated for the geodesic flow. Our results indicate that in some cases, e.g. for the so-called 'vertical precession resonance' model, the presence of pressure forces may have a major influence on the predicted ranges of spin. On the other hand, in other cases, e.g. for the so-called 'Keplerian resonance' model, the predicted 'non-geodesic' spin intervals do not much vary from those corresponding to geodesic calculations.

126.21 – Diskoseismology and QPOs Confront Black Hole Spin

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We compare the determinations of the angular momentum of stellar mass black holes via the continuum and line methods with those from diskoseismology. The assumption being tested is that one of the QPOs (quasi-periodic oscillations) in each binary X-ray source is produced by the fundamental g-mode. This should be the most robust and visible normal mode of oscillation of the accretion disk, and therefore its absence should rule out diskoseismology as the origin of QPOs. The comparisons are consistent with the second highest frequency QPO being produced by this g-mode, but are not consistent with models in which one QPO frequency is that of the innermost stable circular orbit. The origin of the highest frequency (3/2 greater) QPO remains a mystery that we are investigating.

126.22 – Discovering Nearby Compact Objects with Gravitational Lensing

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Within a kiloparsec of Earth there are more than 10 million black holes, and ten times as many neutron stars. These compact objects have proved difficult to discover, and only a handful have been identified. Black holes and neutron stars regularly serve as gravitational lenses, however. We report on our efforts to use existing and new data to use their action as lenses to discover them. For example, several percent of the 2000 lensing events found by the OGLE and MOA teams each year are generated by nearby compact objects. We describe how this optical data, combined with x-ray data, including some to be collected by new Chandra programs, can be used to identify those events caused by compact objects. If this approach is successful, direct mass measurements will be carried out on a regular basis.

126.23 – A Swift Survey of Accretion onto Stellar-Mass Black Holes

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We present a systemic analysis of all of the stellar mass black hole binaries (confirmed & candidate) observed by the Swift observatory up to June 2010. The broad Swift bandpass enables a trace of disk evolution over an unprecedented range in flux and temperature. The observed spectra have an average luminosity of $\sim 1\%$ Eddington, though we are sensitive to accretion disks down to a luminosity of $10^{-3} L_{\text{Edd}}$. We will present the primary results of this survey: (i) There is no evidence for large scale truncation of the accretion disk in the hard state (at least for $L_x \gtrsim 10^{-3} L_{\text{Edd}}$), with all of the accretion disks having radii $\lesssim 40 R_g$. (ii) The broadband spectra (X-ray – Opt/UV) reveal irradiation of the accretion disk to be an important effect at all luminosities sampled herein, i.e., $L_x \gtrsim 10^{-3} L_{\text{Edd}}$. (iii) The Swift data reveal a relation between the flux emitted by the accretion disk and that emitted by the corona that is found to be in broad agreement with the observed disk – corona relationship in Seyfert galaxies, suggesting a scale invariant coupling between the accretion disk and the corona.

126.24 – The Quiescent X-ray Spectrum: Constraints from Stellar Mass Black Holes

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The quiescent state ($L_x \lesssim 10^{-6} L_{\text{Edd}}$) is the dominant accretion mode for black holes on all mass scales. However, our knowledge of the X-ray spectral shape is limited by the combination of low S/N and the presence of significant contamination in the case of SMBHs. Galactic stellar mass black holes present an environment free of the contamination present in galactic nuclei, but are still affected by low S/N. Here, we present a re-analysis of all archival observations of the dynamically confirmed stellar mass black holes in the quiescent state (resulting in a sample of 8 black holes). The spectra are found to be consistent with a common spectral shape for all systems. Assuming this to be so, we model all spectra simultaneously to obtain the best available constraints on the X-ray spectral shape at low luminosity. These results will be discussed in the context of models for the quiescent accretion flow onto black holes.

126.25 – Constraints on Deviations from the Kerr Metric by XTE J1550-564

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Recently, the spin of the galactic black hole XTE J1550-564 has been measured using spectral fits of its thermal disk emission and relativistically broadened iron line. In addition, over the lifetime of the Rossi X-ray Timing Explorer (RXTE), quasi-periodic oscillations (QPOs) have been detected repeatedly at frequencies that cluster around 180 Hz and 280 Hz with an approximate 3:2 frequency ratio. In this talk, we infer the most likely centroid frequency of each cluster as well as the underlying fundamental mode using Bayesian techniques. We then use the combination of all the spectral and QPO data to constrain potential deviations from the Kerr metric as a test of the no-hair theorem assuming two particular QPO models. These models may be distinguished by the Large Observatory For x-ray Timing (LOFT), one of five candidates for ESA's next M3-class mission.

126.26 – Evidence of Energy-dependence of Power Spectral States of Black Hole Binaries and the Origin of the X-ray Variability

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In the conventional picture of black hole X-ray spectral states, there is a correspondence between the individual X-ray spectral state and the power spectral state. However, in the Swift and the RXTE observations of the 2010 outburst, the black hole transient MAXI J1659-152 showed power spectra of a power-law noise (PLN) below 2 keV and a band-limited noise (BLN) plus quasi-periodic oscillations above 2 keV, respectively. The emergence of the PLN and the fading of the BLN and QPOs took place from below 2 keV when the source entered the hard intermediate state and finally settled in the soft state three weeks later. This was accompanied by the emergence of the disk spectral component and the decreases of the variability amplitudes in the UV, the soft X-ray and the hard X-ray bands. Our results support that the PLN is associated with the optically thick disk in both hard and intermediate states, and the X-ray power spectral state is independent of the energy spectral state in a broadband view, challenging the conventional description of black hole X-ray states. We suggest that the energy cut-offs of the PLN and the BLN or QPOs follow the temperature of the seed photons from the inner edge of the optically thick disk which generates the observed energy-dependence.

126.27 – Using CCI to Unravel the States of GRS 1915+105

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We use Color-Color-Intensity (CCI) diagrams (Vrtilek & Boroson, 2012) to explore the states of the black hole binary (BHB) system GRS 1915+105. Assuming the changes in the loci of these states in the CCI phase space to be due to intrinsic properties of the sources (such as mass accretion rate and radio jets), we analyze the regions of CCI phase space and its relation to these properties. We explore the possible correlation of mass accretion rate and X-ray color. We find no simple trend in mass accretion rate on the HR1-HR2 plane. We also plot the jet-line proposed by Fender et al. (2004) in CCI phase space and compare the jet and non-jet states of another GRS-like system, 4U 1630-472. We find that the states of 4U 1630-472 are compatible with the jet-line.

126.28 – Results, Constraints, and Remaining Challenges in Testing Time-dependent Accretion Theory Against Observations of Viscous-timescale Variability in LMC X-3

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Many aspects of the black hole X-ray binary LMC X-3 render it an ideal system for testing time-dependent accretion theory on viscous timescales, which more generally informs us about the same variability mechanisms as they appear in contexts like transients, and the accretion flow conditions feeding into processes like jet launching. We first review results of modeling, described in a recently submitted paper, that considered Compton-heated winds, bifurcation between disk and corona flows at the outer edge, modulation of the total supply rate by accretion X-rays irradiating the companion, and evaporation and condensation between disk and corona using the solutions of Liu et al. (2007ApJ...671..695L). We found that a generous combination of the former three were unable to explain the variability in LMC X-3. Including evaporation and condensation with a highly-simplified corona model often predicted instances of correlated disk and corona accretion rates in conflict with data, but invoking suppressed condensation at inner radii led to fairly good agreement. We then examine such suppression more critically and quantitatively, and describe our latest work towards treating the corona more self-consistently.

126.29 – Properties and Distribution of Current Sheets in Accretion Disk Coronae

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Theoretical models involving the interplay of a geometrically thin, optically thick accretion disk embedded in an extended coronal atmosphere may describe black hole X-ray binaries across all spectral states. Buoyant magnetic field generated in the accretion disk is continuously supplied to the corona by a dynamo process driven by the magnetorotational instability. This rising field leads to the formation of a magnetic pressure-dominated, low-density, geometrically thick corona where substantial accretion energy is dissipated, likely by collisionless magnetic reconnection, perhaps even generating outflows. Despite the potential importance of magnetic reconnection in shaping the energetics and kinematics of the corona, studies of multiple reconnection sites in a large volume are currently prohibited by the computational expense required to properly treat the microphysical nature of reconnection. Under the assumption that coronal structure is determined by ideal magnetohydrodynamics, we analyze local simulations of accretion disks (i.e., shearing boxes) performed with the ATHENA code, where the spatial domains are extended to capture 'mesoscale' structures that are dynamically important in accretion disk evolution. We employ a

location routine to identify zones of enhanced current density, which trace likely sites of magnetic reconnection. We describe the positions, orientations, sizes, shapes, strengths, and kinematics of these regions and correlate them with the spatial distribution of numerical dissipation. Statistical distributions of these various properties of current density zones are presented to determine the heights within the corona that contribute most to the dissipation rate, the flow properties associated with reconnection sites, and representative parameters for future large volume reconnection simulations.

126.30 – Testing the Stability of Three-Dimensional Hoyle-Lyttleton Accretion with Large Upstream Gradients

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Supergiant Fast X-Ray Transients (SFXTs) are a subclass of high mass X-ray binaries exhibiting luminosities as high as 10^{37} erg/s, a dynamic range of 10^4 erg/s, and a duty cycle lasting only hours to days. The outburst mechanism responsible for SFXT flaring is currently unknown. Potential mechanisms include the accretion of a clumpy wind produced by wind instabilities in the donor star, accretion from an anisotropic wind such as a Be star disk wind, or hydrodynamic instabilities intrinsic to the accretion process. We seek to test these mechanisms through numerical simulations of Hoyle-Lyttleton accretion (HLA), which describes the gravitational accretion of a supersonic ideal gas onto a compact object. HLA has been shown to be dynamically unstable in two-dimensional planar simulations. By contrast, three-dimensional HLA is remarkably stable in the presence of a uniform upstream flow. It has yet to be determined what upstream conditions would be sufficient to disrupt this stability and produce bursts of mass accretion with magnitudes corresponding to those seen in SFXT flares. To probe the stability in the presence of large upstream density and velocity gradients, we extend the model of Blondin & Raymer (2012), which utilizes spherical overset grids to achieve previously unmatched spatial resolutions. For an ideal gas with an adiabatic index of 5/3, the presence of 20% and 100% gradients across the upstream accretion column can induce intermittent rotational flow that occurs behind a deformed bow shock. These transient vortices are frequently interrupted by brief periods of chaotic flow, during which slightly enhanced mass accretion can occur. The net effect of the rotational flow is to inhibit the mass accretion rate, which is less than the Hoyle-Lyttleton prediction by up to an order of magnitude.

126.31 – A Hybrid Model for the Spectra of Neutron Star Accretion Columns Including Comptonization and Cyclotron Lines

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A physical model for the radiation emitted from accretion columns of neutron stars with magnetic fields on the order of 10^{12} G has to reflect the large-scale dynamical structure of the inflowing matter as well as the quantum mechanical scattering processes leading to the formation of cyclotron resonant scattering features (CRSFs). Becker & Wolff (B&W) developed an analytic model for the broadband continuum while the CRSFs have been investigated by Schönherr & Schwarm (S&S). While both models describe the separate trends seen in observational data very well, a fully self-consistent fitting approach to determine the physical parameters (e.g., accretion rate, magnetic field strength) of the accretion column in accreting X-ray pulsars requires accounting for both processes in one unified model. We present our first approach towards such a unified hybrid model covering both the macro- and the microphysics of the accreting plasma. We assume a cylinder symmetrical dual layer structure of the accretion column. The inner layer reflects the dynamical structure described by the B&W model while the optical thin outer layer acts as a CRSF forming region similar to a photosphere. We adopt the parameters from a fit of the B&W model to Her X-1 and calculate the emergent radiation as well as the dynamical properties such as bulk velocity within the core of the accretion column. Radiation escaping the optical thick core region is further altered by the outer shell, a thin layer with an optical depth on the order of 10^{-4} - 10^{-2} Thomson optical depth, adding cyclotron lines by processing it through the S&S model. This hybrid model is only a first step towards a unified model for accreting neutron stars with strong magnetic fields. In the future we will investigate the insertion of a third layer in the middle as a transition region, parameter boundaries, and also incorporate general relativity with the ultimate goal to use this new tool to model phase-resolved spectroscopy of accreting X-ray pulsars. We would like to thank the ISSI, Bem, for hosting inspiring and productive international team meetings such as the one resulting in the ideas presented here.

126.32 – Accretion Regime of A0535+26 During its 2011 Giant Outburst

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A0535+26 is a Be/X-ray binary hosting a highly-magnetized accreting neutron star. Its $\sim 4 \times 10^{12}$ G magnetic field was derived using the cyclotron lines present in its X-ray spectrum at ~ 45 and ~ 100 keV. Cyclotron lines are very powerful tools: not only do they provide the only direct way to determine a neutron star's magnetic field, but their dependence on the X-ray luminosity can be used to probe the accretion theory. After more than 11 years of quiescence, A0535+26 became active again in 2005 including three giant outbursts since then: the 15-50 keV flux reached ~ 5.2 , ~ 5.6 , and ~ 3.8 Crab in 2005, 2009, and 2011, respectively. While the first two giant outbursts were poorly covered by most X-ray observatories due to Sun observing constraints, we monitored the last one thanks to a TOO with INTEGRAL. Here, we present results of these observations with a special focus on the cyclotron lines present in the X-ray spectrum of the source. The evolution of the cyclotron line parameters with the luminosity are studied in detail for the first time in the ~ 5 -200 keV energy range during a giant outburst of the source, and the results are interpreted in terms of recent theoretical works.

126.33 – High-Mass X-ray Binaries in our Backyard: Studying Their Formation and Evolution in the Magellanic Clouds

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Our nearest star-forming galaxy, the Large Magellanic Cloud (LMC), offers unique insights into the observational characteristics of young (<100 Myr) X-ray binaries (XRBs) in other distant star-forming galaxies for which these faint luminosity levels are out of reach. The number of currently known High-Mass X-ray Binaries (HMXBs) in this galaxy (~40) allows the investigation of the parameters affecting their formation, such as the star-formation rate, the age of the parent stellar populations and the metallicity. Most importantly though, it allows for a direct comparison with the well-studied population of HMXBs in the Small Magellanic Cloud (SMC). We find that the HMXBs (and as expected the X-ray pulsars) are shown in regions with star-formation rate bursts ~6-25 Myr ago, in contrast to the SMC, for which this population peaks at later ages (~25-60 Myr ago), a direct result of the younger parent stellar populations in the LMC. Although the SMC is widely believed to have lower metallicity than the LMC (~1/5Zsun and ~1/3Zsun, respectively), in this work we have used the available star-formation history for the youngest stellar populations, even if this resulted in the same metallicity (~1/2Zsun for Zsun=0.0134) for the HMXB populations in both Magellanic Clouds, thus in this work we do not investigate directly the effect of metallicity. Using the mean offset between each HMXB and its nearest star cluster, we estimate the distance that the HMXBs may have travelled since birth. Although the HMXBs in the LMC seem to travel twice as large distances as their counterparts in the SMC, at the same time they are significantly younger than the HMXBs in the SMC (i.e. with ages of ~6-25 Myr and ~25-60 Myr, respectively). For this reason, we derive similar kick velocities for the HMXBs in both galaxies, which are also in agreement with values estimated for the Galactic systems (~10-20 km/s). The young XRBs are tracers of past populations of massive stars, while the study of their compact objects help us understand general relativity and the physics of ultra-dense matter. This work is supported by the National Aeronautics and Space Administration under Grant No. NNX10AH47G issued through the Astrophysics Data Analysis Program.

126.34 – Exposing the Symbiosis of 3A 1954+319

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Symbiotic X-ray Binaries (SyXB) are a rare class (~8 known members) of Low Mass X-ray Binaries (LMXB), in which a compact object accretes material from an evolved M-type giant. The SyXB and accreting pulsar 3A 1954+319 is further exceptional since it has the longest pulse period known for an X-ray binary. It undergoes rapid changes, which we found span a range of 5.0-5.8 hours over the interval 2005-2012 monitored with Swift-BAT, probably an indication of the expected strong interaction with the dense M-giant wind. We present an analysis of a Chandra observation performed on 2010, December 26, and an RXTE observation performed on 2011, January 10-11, both spanning two pulse cycles. The Swift-BAT context shows that during both observations the source was in a state of comparatively stable and low hard X-ray flux (at about 15 mCrab, with a pulse period around 5.6 h and overall slowing down). We discuss the broad band "baseline" spectrum and compare it to the two earlier X-ray broad band studies described in the literature. Strong flaring activity on timescales of hundreds to thousands of seconds is observed and studied in the light of a possible accretion shock interpretation.

126.35 – Cyclotron Line Measurements and a Torque Reversal in 4U 1538-522 as Seen by INTEGRAL

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We present an analysis of all public INTEGRAL observations of the high-mass X-ray binary 4U 1538-522. Pulse period measurements strongly suggest that the source underwent a torque reversal in early 2009, departing from its spin-up trend of the past 20 years. We perform a detailed spectral analysis of the INTEGRAL data from either side of this torque reversal, and find few significant changes in the X-ray spectral parameters, both with respect to date (before or after the reversal) and source luminosity. Perhaps most notably, no correlation is found between the centroid energy of the cyclotron line (detected at ~22 keV) and luminosity, a result which is in line with the predictions of Becker et al. (2012)'s work on luminosity regimes in the accretion column. We also make significant detections of the harmonic CRSF at ~50 keV, supporting the results of Rodes-Roca et al. (2009).

126.36 – The Accreting Pulsar XTE J1946+274: Further Indication for a Cyclotron Line from Suzaku?

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We present a timing and spectral analysis of the X-ray pulsar XTE J1946+274 observed with Suzaku towards the end of a weak outburst in 2010 October and compare it with previous results. XTE J1946+274 is an X-ray transient with a Be-type companion and a neutron star with a ~15.8 s pulse period. For this analysis we used both XIS(0,1,3) and PIN data. From the latter we confirm the previously determined pulse period and create pulse profiles for several energy bands. Despite a difference in flux of more than an order of magnitude, we observe a comparatively good match between the pulse profiles for Suzaku and RXTE-PCA, the latter obtained during a different, brighter outburst in 2010, for the 20-40 keV energy range (while small differences are present in the 10-20 keV range). The X-ray spectrum can be well described by a Fermi-Dirac cutoff power law model along with a narrow iron K alpha fluorescence line at 6.4 keV. The strength of the iron line is consistent with the continuum vs. line flux correlation observed in different outbursts of the source. We also investigate the possible presence of a Cyclotron Resonance Scattering Feature (CRSF) at 35 keV, which was detected in data from a previous outburst in 1998, and find marginal evidence for it in the Suzaku data. From an earlier analysis of the brighter 2010 outburst, a possible CRSF residual at 25 keV was reported, which is not visible in the Suzaku data. We discuss possible interpretations with respect to the magnetic field of XTE J1946+274.

126.37 – Toward a New Spectral Modeling Capability for Accreting X-Ray Pulsars

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Spectral modeling of accreting X-ray pulsars can tell us a great deal about the physical conditions in and near the neutron star compact objects in high mass X-ray binary systems. In such systems the accreting plasma is initially channeled from an accretion disk by the strong neutron star magnetic field into a funneled supersonic flow onto the magnetic polar cap of the neutron star. Many of these accreting X-ray pulsars have X-ray spectra that consist of broadband Comptonized power-law X-ray continua with superposed cyclotron resonant scattering features indicating magnetic field strengths above 10^{12} G. We are undertaking a new program to develop a spectral analysis tool based on the analytical work of Becker & Wolff (2007) for accreting X-ray pulsar spectra inside the XSPEC spectral analysis framework. We will apply this new analysis tool to the large amount of data on numerous bright accreting X-ray pulsars currently residing in the HEASARC archive. In this presentation we discuss the physical processes that are likely to occur in such a flow and how one might self-consistently model the broadband pulsar X-ray spectrum. A previous attempt at developing such a modeling capability made significant contributions to the understanding of one source in particular, namely, 4U0115+634 (Ferrigno et al. 2010) and we expect to build on that success. Our models will incorporate bremsstrahlung emission, black body emission, and cyclotron emission, all in a strongly Comptonizing environment inside the shock-heated accreting plasma. We will discuss how we will include these physical processes in the calculations as well as the algorithm such a tool will use to converge to a solution. This program is both feasible and timely in light of the expected launch of the LOFT X-ray timing mission. This research is supported by the NASA Astrophysical Data Analysis Program and the Office of Naval Research.

126.38 – A New Method to Search for Quiescent Low-Mass X-ray Binary

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We explore a new method in searching for quiescent Low-Mass X-ray Binaries (qLMXBs). To date, almost all the accretion-powered BH-LMXBs, which stay in their quiescent state most of the time, were only found during their X-ray outburst. Our method explores a new way to find accretion binaries in their quiescent states. We search objects with spectral types earlier than K and M $_V$ more than 2- σ brighter than that expected for a main-sequence star, then look for stars in the above sample with $\log(F_{X/F_R})$ (0.5-2.0 keV) more than 2- σ greater than that seen in typical subgiant stars. Most likely there is an accretion disk responsible for the extra X-ray emission. We show one example target of this study, with its X-ray and optical data. This approach opens a new way to search for accretion binaries hidden in the Galactic plane.

126.39 – A Multiwavelength Study of the Field Low Mass X-Ray Binaries in the Bulge of M31

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We present an analysis of the low mass X-ray binaries (LMXBs) in over a decades worth of archival Chandra observations of the bulge of M31. We search for the optical counterparts of the field sources (not associated with globular clusters) in deep HST UV, optical, and IR images in order to understand the genesis of these sources. It is quite difficult for field star populations to produce tightly bound LMXBs. Theoretical studies suggest that the majority of the bright field LMXBs ($L_x > 10^{37}$ ergs/s) are systems with red giant donors. The large hot disks and/or the donor stars of such objects should be detectable in our deep HST mosaic images. We find surprisingly few counterparts. We discuss these sources and the implications of our observations on the formation channels of field LMXBs.

126.40 – Monitoring the Spectral and Flux Evolution of MAXI Discovered Galactic Black Hole Candidates with Swift

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The 'Monitor of the All-Sky X-ray Image' (MAXI) is a Japanese X-ray telescope mounted on the International Space Station, consisting of two 1-D coded mask slit detectors (the Gas Scintillation Camera: GSC, and Solid State Camera: SSC) which scan the majority of the sky every 93 minute ISS orbit, in the 0.5-20 keV range. This range makes it ideal for the early discovery of Galactic X-ray transients. Utilizing Swift we have a program of accurately localizing, and then monitoring these new transients in both X-ray and Optical/UV with short (1ks) daily-weekly observations over the duration of their outburst. These observations allow us to track both the spectral and flux evolution of the outburst, as well as in some cases, detect temporal variations such as QPOs and orbital periodicities. In this poster we present results from the program over the last 12 months, including results from MAXI J1305-704.

126.42 – Probing the Accretion-flow Dynamics using an Energy Dependent Timing Analysis in Black Hole X-ray Binaries

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I present a timing study of the black hole X-ray binary (BHB) SWIFT J1753.5-012, which for the first time uses the Swift X-Ray Telescope (XRT) to measure the energy dependence of all power spectral components. The soft (< 2 keV) and hard (> 2 keV) band show dramatically different behavior, suggesting that the hot flow is more variable in the peak of the outburst and the disk is more variable at low intensities. This result is important in understanding the role of the disk in the origin of the variability and how it stabilizes in (and towards) the high state when the source shows very little (or no) variability. I will also discuss ongoing XRT work on two more BHBs (MAXI J1659-152 and GX 339-4) one result of which is that the low frequency (< 10 Hz) Quasi Periodic Oscillation (QPO) is more coherent in the hard band than in the soft band, and the strong implications this has for our understanding of the geometry of the accretion flow that provides the driving mechanism (Lense-Thirring precession of the hot inner flow). Swift XRT timing study is making an important contribution to understanding accretion onto black holes as it allows us to probe the energies below 2 keV which were inaccessible to the Rossi X-ray Timing Explorer, but timing with the XRT has some issues and potential pitfalls that I shall briefly address.

126.43 – The Nature of the mHz X-ray QPOs from the Ultraluminous X-ray Source M82 X-1: Timing-Spectral (anti)-correlation?

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We have analyzed all archival XMM-Newton observations of the ultraluminous X-ray source (ULX) M82 X-1 in order to search for a correlation between its mHz quasiperiodic oscillation (QPO) frequency and energy spectral power-law index. These quantities are known to correlate in stellar mass black holes (StMBHs) exhibiting so-called Type-C QPOs. The detection of a similar relation in M82 X-1 would strengthen the identification of its mHz QPOs as Type-C and thus enable more reliable mass estimates by scaling of the QPO frequencies in X-1 to those of Type-C QPOs in StMBHs of known mass. We used surface brightness modeling to estimate the count rates produced by X-1 and a nearby (5'') bright source that can contribute substantial flux in XMM-Newton's 15'' (HPD) beam. We thus identify the observations in which M82 X-1 is at least as bright as the nearby source. In these observations we detect mHz QPOs with centroid frequencies spanning the range from 36 mHz to 210 mHz (the lowest and the highest yet reported from X-1). We model the 3-10 keV spectrum and find that the power-law index changes significantly from 1.7 - 2.2 during these observations. With all observations included we find evidence for an anti-correlation between the centroid frequency of the mHz QPOs and the power-law index. The value of the Pearson's correlation coefficient is -0.95. While such an anti-correlation is observed in StMBHs at high Type-C QPO frequencies (5-15 Hz), the frequency range over which it holds in StMBHs is significantly smaller (factor of 1-3) than the QPO range now reported here for X-1, which varies over a factor of 5.8 (36-210 mHz). However, we note that the correlation hinges on the observation with the lowest inferred energy spectral index and for which the fitted count rate ratio of X-1 to the nearby source is 1.1. So the implied anti-correlation needs to be confirmed with either less 'contaminated' observations or higher angular resolution spectral measurements made in tandem with QPO detections. Nevertheless, our results demonstrate that the wide range of QPO frequencies now seen in X-1 should eventually enable a careful exploration of the timing - spectral correlations needed to test the Type-C identification.

126.44 – Tests of General Relativity in the Strong Gravity Regime Based on X-Ray Observations of Black Holes in X-Ray Binaries

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Although General Relativity (GR) has been tested extensively in the weak gravity regime, similar tests in the strong gravity regime are still missing. In this contribution, I report on a study of the observational signatures of non-Kerr spinning black hole metrics based on the family of phenomenological metrics introduced by Johannsen and Psaltis (2011). The conservation laws of mass, energy, momentum, and angular momentum are used to infer the radial brightness of Novikov-Thorne-type accretion disks in the non-Kerr spacetimes. The analytical accretion disk solutions are combined with a ray tracing algorithm to calculate the observable X-ray energy spectra and polarization signatures. Although the X-ray emission properties do depend strongly on the properties of the background metric, it is rather difficult to distinguish between the Kerr metric and alternative metrics as long as the spin of the black hole cannot be measured independently. I will discuss possibilities to break the degeneracy between the parameters describing the deviation from the Kerr metric and the black hole spin.

126.45 – Constraints on R-mode Amplitudes in LMXB Neutron Stars: Probing the Phases of Ultra-dense Matter

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The phases of ultra-dense neutron star (NS) matter can be probed with X-ray observations that constrain the evolution of the dynamic properties of NSs, such as their spin period and temperature. While their bulk properties, such as mass and radius, depend on the equation of state (EOS) of dense matter, the dynamic properties of NSs also depend on the low energy degrees of freedom, because they are affected by the transport and thermodynamic properties of dense matter such as neutrino emissivity, viscosity and heat capacity. As different phases of dense matter have very different low energy degrees of freedom, the dynamic properties of NSs can efficiently discriminate between them. The r-mode oscillations of NSs can be potentially powerful probes of ultra-dense NS matter, because they couple the low energy degrees of freedom of dense matter to macroscopic dynamic observables, such as the spin period. Here we present upper limits on the amplitude of r-mode oscillations, and their gravitational-radiation-induced spin-down rates, in LMXB neutron stars under the assumption that the quiescent NS luminosity is powered by dissipation from a steady-state r-mode. We calculated results for NS models constructed with the APR EOS for masses of 1.4, 2 and 2.21 M_{\odot} . For the lower mass NS models (1.4 and 2 M_{\odot}) we find dimensionless r-mode amplitudes in the range from about 1×10^{-8} to 1.5×10^{-6} . At these amplitudes less than 2% of the observed, quiescent spin-down rates in these sources can be due to gravitational radiation from unstable r-modes. Our highest mass model (2.21 M_{\odot}) can support enhanced, direct URCA neutrino emission in the core and thus can have higher r-mode amplitudes. Indeed, the inferred r-mode spin-down rates at these higher amplitudes are inconsistent with the observed spin-down rates for some of the LMXB sources, such as IGR J00291+5934 and XTE J1751-305. This can be used to put an upper limit on the masses of these sources if they are made of normal nuclear matter, or it could be used to probe the existence of exotic matter in these sources if the NS mass in these systems were known.

126.46 – Collisionally Heated Disk Dynamics and Torque Reversals in the Ultracompact Binary 4U 1626-67

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We observed the ultracompact binary pulsar 4U 1626-67 with the Chandra High Energy Transmission Grating Spectrometer two years after it experienced a second torque reversal. The X-ray spectra favor a collisionally ionized plasma with enhanced plasma densities and plasma temperature between 1 MK and 10 MK. The nature of the Doppler line pairs can be modeled as Keplerian disklines from a shocked accretion disk near the magnetosphere and the disk line fits constrain the angle inclination to 38 degrees. This is consistent with a CO white dwarf companion. Under the assumption that the disk heating is related to the magnetospheric boundary, we then observe a direct relation between the magnetospheric radius and the disk co-rotation radius, naturally explaining the change from spin-down to spin-up episodes. We discuss the underlying model assumptions and implications for torque reversal episodes in other binary pulsars.

126.47 – The Spectral Evolution along the Z Track of the Bright Neutron Star X-Ray Binary GX 17+2

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We analyze 68 observations of Sco-like Z source GX 17+2 taken by RXTE in 1999 Oct, covering a complete Z track. We fit color-resolved spectra with a

model consisting of a thermal multicolor disk, a single-temperature-blackbody boundary layer and a weak Comptonized component. The Comptonization seed photons are tied to the thermal disk component and corrected for to recover the pre-Comptonized thermal disk emission. We find a constant \dot{M} into the disk along the entire Z track based on the thermal disk component. The branches can be explained by three processes: increase of Comptonization up the horizontal branch, transition from a standard thin disk to a slim disk up the normal branch, and temporary fast decrease of the inner disk radius up the flaring branch. Our results also support identification of the upper kHz QPO frequency as the Keplerian frequency at the inner disk radius and close relation between the horizontal branch oscillation and the dynamics in the inner disk.

126.48 – Preliminary Results of the NuSTAR Galactic Center Mini-survey

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In October 2012, the Nuclear Spectroscopic Telescope Array (NuSTAR) observed the Galactic Center region. This observation, with 150 ksec total exposure time and 6 pointings between Sgr A* and 1E1743.1-2843, was conducted as the first part of the 2x0.8 degree Galactic Center survey. NuSTAR's Galactic Center survey will address some of the long-standing questions in high-energy astrophysics - the nature of numerous X-ray sources discovered by Chandra, the origin of hard X-ray emission from Sgr A* and its vicinity, the nature of the Galactic diffuse X-ray background and the question of whether the Galactic Center molecular clouds are illuminated by cosmic-ray bombardment or Sgr A* flares in the past. In this talk, I will present the first high-resolution image of the Galactic Center region above 10 keV. With NuSTAR's sub-arcminute angular resolution, we can unambiguously resolve and identify various sources such as Sgr A East, the Plume, the Sgr A-E knot, the Arches cluster and various molecular clouds. Combined with high-resolution spectral analysis from 3 to 40 keV, NuSTAR elucidates the origin of the hard X-ray emission from the Sgr A* region and several bright molecular clouds in the Sgr A complex. We did not find the putative hard X-ray source J17456-2901 discovered by INTEGRAL. Some preliminary results from point source detection and diffuse X-ray background analysis will be also presented.

126.49 – Distribution of High Mass X-ray Binaries in the Milky Way

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INTEGRAL observations have raised new questions about the evolution of High Mass X-ray Binaries (HMXBs) from their formation to the accretion stage in which these objects are detected in high energy. The number of detected HMXBs of different types is now high enough to allow us to carry out a statistical analysis of their distribution in the Milky Way. For the first time, we accurately derived the distance and absorption of a substantial sample of HMXBs by using a Spectral Energy Distribution fitting procedure. This study (ApJ in press) leads to a novel and accurate cartography of HMXBs in the Milky Way. Then, we examine the correlation with the distribution of Star Forming Complexes (SFCs) in the Galaxy. We will show that HMXBs are clustered with SFCs with a typical cluster size of 0.3 kpc and a characteristic distance between clusters of 1.7 kpc. Furthermore, we will present an investigation of the expected offset between the position of spiral arms and HMXBs, allowing us to constrain age and migration distance due to supernova kick for 13 sources. These new results, related to the first Herschel data of a sample of HMXBs will allow us to assess the influence of the environment on these high energy objects with unprecedented reliability.

126.50 – X-ray Binaries and Their Makers

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Exploring the relations between star formation activity, stellar mass distribution and luminous X-ray binaries (XRBs) often results in considerable progress in understanding the nature, formation, and diversity of the different classes of X-ray binaries. Over the last decade, several studies have demonstrated the existence of a tight correlation between the collective number and luminosity of short-lived (< 10-50 Myr) high-mass X-ray binaries (HMXBs) as well as ultra-luminous X-ray sources (ULXs) and the integrated star formation rate (SFR) of late-type host galaxies. It is also known that the collective number and luminosity of long-lived (> 1 Gyr) low-mass X-ray binaries (LMXBs) correlate well with the integrated stellar mass of host early-type galaxies and bulges of late-type galaxies. We report on our recent results that introduce a new multi-wavelength technique to explore these correlations in greater detail. We have constructed spatially-resolved images of SFR density using combinations of Galex FUV and Spitzer 24 μ m images. We have also obtained stellar mass surface brightness maps using combinations of 2MASS H-band and SDSS g- and i-band images. By means of these maps we have investigated the spatial and luminosity distributions of XRBs detected with Chandra in star-forming and early-type galaxies as a function of the local SFR and stellar mass densities respectively, around the X-ray sources. This method was first applied to study the population of ULXs in the colliding galaxy pair NGC 2207/IC 2163 and the population of LMXBs in the elliptical galaxy NGC 4649. We find that the number and luminosity of both young XRBs per unit SFR and old XRBs per unit stellar mass are in agreement with those predicted by the galaxy-wide average relations. We will also report on preliminary results of an ongoing and much more extensive work in which the same method is being applied on a significantly larger number of X-ray sources detected in a sample of nearby grand-design spiral galaxies to characterize the spatial dependence of X-ray luminosity functions for the different classes of XRBs.

126.51 – The Puzzling Globular Cluster System of ESO 243-49 Hosting the Intermediate Mass Black Hole HLX-1

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I will present a study of the colors and spatial distribution of globular clusters in the galaxy ESO 243-49. This galaxy hosts the best intermediate mass black hole candidate currently known, possibly located in the remnant of a dwarf galaxy being accreted by the main galaxy. We observe an asymmetry in the distribution of globular clusters that is possibly due to the accretion of another dwarf galaxy. Those processes, caught at a unique moment, may indicate how the globular cluster system of a galaxy builds up. In particular, the remnant of a stripped dwarf galaxy possibly hosting an intermediate mass black hole might survive and later resemble a globular cluster.

126.52 – Discovery of a Highly Variable ULX Within NGC 4736

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We report our discovery of a new ultraluminous X-ray source within the Seyfert galaxy NGC 4736, which shows many intriguing properties. The source has been observed by ROSAT, Chandra, and XMM-Newton on several occasions, with a flux variation of at least a factor of 26 and a peak absorbed luminosity of 2.1×10^{39} erg/s in the 0.3-10 keV band. The source is better fitted with a multicolor disk in the high state, but a hard powerlaw is favored in the low state, indicating the observation of a possible spectral state transition that is similar to that seen in Galactic black-hole X-ray binaries. In the brightest observation, which was made by XMM-Newton, we also find some evidence of dipping. In a 14 hr low-state observation made by Chandra, the light curve seems to show a ~ 7 hr periodic modulation over two cycles. Thus, the source is probably a highly variable, dipping and periodic black-hole X-ray binary with the black-hole mass about a few tens of solar mass. We discuss the importance of this source on helping us understand the nature of the ultraluminous X-ray sources.

126.53 – The 62 Day X-ray Period of the Ultra-luminous X-ray Source M82 X-1 is Likely Super-orbital

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We have analyzed all archival RXTE/PCA monitoring observations of the intermediate-mass black hole (IMBH, mass range of a few 100-1000 solar masses) candidate and ultraluminous X-ray source (ULX) M82 X-1 in order to study the properties of its previously discovered 62 day X-ray period. The high average X-ray luminosity of M82 X-1 (roughly 5×10^{40} ergs/sec) suggests that the compact source is very likely a black hole. Given that there are no known black hole binaries with super-orbital periods as short as 62 days (the shortest known black hole super-orbital period is a factor of 3 longer), it has been argued that the observed period is the orbital period of the binary. Using approximately 2000 days of RXTE/PCA monitoring data obtained with an observing cadence of approximately once every 3 days, we studied the stability of this period. We find clear evidence for phase evolution of the light curve that can be modeled with a period derivative of -0.009 sec/sec. This value indicates that the 62 day X-ray period's phase is changing with a timescale (period/period derivative) of ~ 20 years. Such a value is unusually fast for any known orbital evolution phenomenon. Similar, rapidly evolving periods have been previously reported from some accreting compact binaries and have been ascribed to a precessing accretion disk. Furthermore, we extracted the average phase-resolved X-ray energy spectra of the source (3-15 keV) and fit them with a model consisting of a standard thermal accretion disk and a power-law. We find that it is the disk's contribution to the total flux that is responsible for the periodic modulation while the power-law flux remains constant with phase. This is also consistent with a precessing accretion disk as the observed variations in X-ray intensity in this model can be ascribed to changes in the projected area of the accretion disk. We argue that these two lines of evidence suggest that the previously reported 62 day X-ray period may be super-orbital in nature.

126.54 – GRS 1758-258: Long Term Evolution of a Rare Persistent Hard State Black Hole

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We present the spectral and timing evolution of GRS 1758-258, one of only three known persistent black hole binaries in our Galaxy, based on 11 years of RXTE-PCA observations. During this time, GRS 1758-258 enters a thermally dominated soft state seven times, showing a strong decline in the 3-10 keV flux rather than an increase. There is only one other source that displays this behavior. In its low energy hardness intensity diagram, GRS 1758-258 shows a hysteresis of hard and soft state fluxes typical for transient sources in outburst. The spectral flux light curve does not contain any orbital modulations in the range of 1 to 30 days, but in the dynamic power spectrum significant peaks are drifting between 18.47 and 18.04 days.

126.55 – A Comprehensive Study of GBM Bursts of SGR J1550-5418

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Contributing teams: GRB Magnetar Team

Starting in October of 2008 and continuing through April of 2009, the Fermi Gamma-ray Burst Monitor (GBM) observed three periods of activity from SGR J1550-5418. Over the course of these outburst periods, GBM observed several hundred bursts from this source. We have performed analysis on all the bursts, and identified significant spectral evolution between the first and the other two periods. While a single blackbody function best describes the bursts of the first period, a two black body model best describes those of the second; more than one model fits the bursts of the third period equally well (OTTB, BB+BB, Comptonized model). These results show an evolution in the burst emission mechanism of the source. We have analyzed a sample of ~ 66 bursts within the tail of the second period to identify the onset of spectral changes, without success. Finally, we present a comprehensive review of all temporal and time-integrated spectral analyses of the entire set of GBM bursts (~ 384 bursts) from this source.

126.56 – Multi-wavelength Observations of Cyg X-3 During a Hard X-ray Flare

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Contributing teams: VERITAS Collaboration

We present the results of multi-wavelength observations of the microquasar Cygnus X-3 which was detected by the Burst Alert Telescope (BAT) onboard the Swift observatory to be in a hard X-ray (10-150 keV) flaring state on March 23, 2012. Since the VERITAS collaboration has initiated a plan to perform follow-up observations of hard X-ray transients detected by the BAT, this event prompted observations with the VERITAS array of imaging atmospheric Cherenkov

telescopes on the nights of March 24 and 27, 2012. A significant very high energy (VHE; $E > 100 \text{ GeV}$) signal was not seen from the micro quasar. In addition to the BAT and VERITAS observations, we will present the results of an analysis of Fermi LAT data in the 200 - 300,000 MeV band from the flaring period. Although the exact physics are currently unclear, observations over the entire electromagnetic spectrum can provide insight to the physical phenomena producing the flares.

126.57 – Simultaneous Chandra/Swift Observations of the RT Cru Symbiotic System

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Contributing teams: Chandra Calibration

The symbiotic star RT Cru was observed simultaneously by the Chandra/HRC-I and Swift/XRT in Dec 2012. The observations were carried out as part of a program to calibrate the Chandra PSF. The Chandra light curve shows a number of brightenings by factors of 2, with strong indications of a softening of the spectrum at these times. Swift observations cover a brief part of the Chandra light curve, and the intensities over this duration are tightly correlated. The Swift spectral data confirm the anticorrelation between intensity and spectral hardness. However, there are differences in the correlations at different periods that are not understood. We report on our analysis of the data, with emphasis on the spectral modeling at different times and intensity levels, and discuss the implications of the results on the emission mechanisms on symbiotic stars. We also report our inferences on the structure and energy dependence of the Chandra PSF anomaly, and on the high-energy cross-calibration between the HRC-I and XRT. This work is supported by the NASA contract NAS8-03060 to the Chandra X-ray Center.

127 – Supernova Remnants and Gamma-ray Bursters

127.01 – Characterization of the Optical and X-ray Properties of the Northwestern Wisps in the Crab Nebula

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We have studied the variability of the Crab Nebula both in the visible and in X-rays. Optical observations were obtained using the Nordic Optical Telescope in La Palma and X-ray observations were made with the Chandra X-Ray Observatory. We observe wisps forming and peeling off from the region commonly associated with the termination shock of the pulsar wind. We measure a number of properties of the wisps to the Northwest of the pulsar. We find that the exact locations of the wisps in the optical and in X-rays are similar but not coincident, with the X-ray wisp preferentially located closer to the pulsar. Our measurements and their implications are interpreted in terms of a MHD model. We find that the optical wisps are more strongly Doppler boosted than X-ray wisps, a result inconsistent with current MHD simulations. Indeed the inferred optical boosting factors exceed MHD simulation values by about one order of magnitude. These findings suggest that the optical and X-ray wisps are not produced by the same particle distribution, a result which is consistent with the spatial differences. Further, the X-ray wisps and optical wisps are apparently developing independently from each other, but every time a new X-ray wisp is born so is an optical wisp, thus pointing to a possible common cause or trigger. Finally, we find that the typical wisp formation rate is approximately once per year, interestingly at about the same rate of production of the large gamma-ray flares.

127.02 – Hard X-ray Variations in the Crab Nebula

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In the first two years of science operations of the Fermi Gamma-ray Burst Monitor (GBM), August 2008 to August 2010, a ~7% (70 mcrab) decline was discovered in the overall Crab Nebula flux in the 15 - 50 keV band, measured with the Earth occultation technique. This decline was independently confirmed with four other instruments: the RXTE/PCA, Swift/BAT, INTEGRAL/IBIS, and INTEGRAL/SPI. The pulsed flux measured with RXTE/PCA from 1999 to 2010 was consistent with the pulsar spin-down, indicating that the observed changes were nebular. From 2001 to 2010, the Crab nebula flux measured with RXTE/PCA was particularly variable, changing by up to ~3.5% per year in the 15-50 keV band. These variations were confirmed with INTEGRAL/SPI starting in 2003, Swift/BAT starting in 2005, and Fermi GBM starting in 2008. Before 2001 and since 2010, the Crab nebula flux has appeared more stable, varying by less than 2% per year. I will present updated light curves in multiple energy bands for the Crab nebula, including recent data from Fermi GBM, Swift/BAT, INTEGRAL and MAXI, and a 16-year long light curve from RXTE/PCA.

127.03 – Modeling Gamma-ray Flares in the Crab Nebula

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The gamma-ray emission from the Crab Nebula shows variations on a wide range of time scales, with the most dramatic events being the flares observed by Fermi and AGILE: the flux can increase by a factor of ~10 within ~10 hours; the spectrum is characterized by a peak energy ~300 MeV, while no variation in other wavebands was detected. These variations present a great challenge to particle acceleration mechanisms. We consider two possible explanations of these flares. Firstly, we consider emission from a moving relativistic shock terminating the pulsar wind. Secondly, we treat the pulsar and its wind as a current generator and suppose that the current filaments into individual pinches that can undergo radial collapse and become strongly dissipative when the electric field becomes as strong as the magnetic field and Larmor radius of the highest energy particles becomes comparable with the radius. The application of these models to pulsar wind nebulae and relativistic jets will be outlined.

127.04 – Mapping the X-ray Structure of Vela X

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Vela X, the wind nebula powered by the Vela Pulsar, is characterized by a distorted structure consistent with disruption through interaction with the asymmetric reverse shock in the Vela SNR. X-ray studies reveal an elongated hard-spectrum region along with evidence for thermal emission from ejecta that have been mixed into the PWN. Gamma-ray studies reveal extended TeV emission concentrated along this region of hard X-rays, while GeV emission is also seen throughout Vela X, but with the brightest emission found distinctly offset from the TeV peak. Here we report on an XMM Large Project to map the X-ray emission over a significant portion of Vela X in order to determine the spectral structure of the nonthermal emission and the plasma properties associated with the thermal emission. We find clear evidence for temperature and ionization variations in the shocked ejecta, and also for a softening of the nonthermal emission with distance from the central regions of the PWN, with the exception of in the region of the GeV emission peak. We present the results from our

spectral studies and discuss these results in the context of the evolution of late phase PWNe.

127.05 – Spatially-resolved Spectroscopy of the IC443 Pulsar Wind Nebula and Environs

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Deep Chandra ACIS observations of the region around the putative pulsar, CXOU~J061705.3+222127, in the supernova remnant IC443 confirm that (1) the spectrum and flux of the central object are consistent with a rotation-powered pulsar interpretation, (2) the non-thermal surrounding nebula is likely powered by a pulsar wind, and (3) the thermal-dominated spectrum at greater distances is consistent with emission from the supernova remnant. The observations further reveal, for the first time, a ring-like morphology surrounding the pulsar and a jet-like structure oriented roughly north-south across the ring and through the pulsar location. The cometary shape of the nebula, suggesting motion towards the southwest, appears to be subsonic; there is no evidence for a strong bow shock and the ring, presumably formed at a wind termination shock, is not distorted by motion through the ambient medium.

127.06 – Heavy-Element Ejecta in G1.9+0.3

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G1.9+0.3 is the youngest known Galactic supernova remnant (SNR), with an estimated supernova (SN) explosion date of about 1900, most likely located near the Galactic center. Only the outermost ejecta layers with free-expansion velocities in excess of 18,000 km/s have been shocked so far in this dynamically-young, likely Type Ia SNR. A long (980 ks) Chandra observation in 2011 allowed for spatially-resolved spectroscopy of heavy-element ejecta. We denoised Chandra data with the spatio-spectral method of Krishnamurthy, Raginsky, & Willett, and then used a wavelet-based technique to spatially localize thermal emission produced by intermediate-mass elements (IMEs: Si, S, Ar, and Ca) and by iron. The spatial distribution of both IMEs and Fe is extremely asymmetric and inhomogeneous, with the strongest ejecta emission in the northern limb. Fe K emission is particularly prominent there, and fits with a thermal plane-shock model indicate strongly oversolar Fe abundances. In a localized, outlying region in the northern shell, IMEs are at least 5 times less abundant than Fe (by mass), indicating that undiluted Fe-group elements (including radioactive Ni) with velocities > 18,000 km/s were ejected by this SN. More modest (up to a factor of 2) Fe overabundances with respect to IMEs are present in other locations within the northern limb. There are several thousandths of a solar mass of shocked Fe in G1.9+0.3. In several locations within the remnant, including the (inner) west limb, we also find Si- and S-rich ejecta without any traces of Fe, so high-velocity, presumably undiluted products of O-burning were also ejected by the SN. If the underlying continuum is thermal, with plasma temperatures of 3-4 keV, then it must be produced by lighter elements such as O that comprise the bulk of the shocked gas. We discuss these findings in the context of Type Ia SNe such as SN 2010jn where iron-group elements at such high free-expansion velocities have been recently detected. We also discuss the origin of the bright northern radio shell in terms of shock-accelerated positrons produced in the decay of high-velocity radioactive Ni. The Sc line produced in the decay chain of radioactive Ti is present in the SNR's interior.

127.07 – A Decade-Baseline Study of the X-ray Knots of Cas A: The Paradox of Non-Evolution

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We present the analysis of 21 bright X-ray knots in the Cas A supernova remnant from observations spanning ten years. We performed a comprehensive set of measurements to reveal the kinematic and thermal state of the plasma in each knot, using a combined analysis of 2 high energy resolution HETG and 4 medium energy resolution ACIS sets of spectra. The ACIS electron temperature estimates agree with the HETG-derived values for approximately half of the knots studied, yielding one of the first comparisons between high resolution temperature estimates and ACIS-derived temperatures. We did not observe the expected spectral evolution – predicted from the ionization age and density estimates for each knot – in the great majority of the knots studied. The incompatibility of these measurements with our assumptions has led us to propose a dissociated ejecta model, with the metals unmixed inside the knots, which could place strong constraints on supernova mixing models.

127.08 – First Results from an XMM-Newton LP on SN1006

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We present first results from our XMM-Newton large project on SN1006 with total effective exposure times of 683, 710, and 439ks from MOS-1, MOS-2, and PN. We conduct spatially resolved spectroscopy analysis to map out the physical parameters of this closest and least absorbed historical SNR. High-resolution (comparable to the original narrow band images with a pixel size of 3.2') equivalent width (EW) maps are obtained for OVII, OVIII, MgXI, MgXII, SiXIII, SiXIV, SXV, and in particular, Fe L-shell emission lines, using our new continuum fitting method. Many filamentary structures are clearly resolved on EW maps (which are not seen on the original images), consistent with results from numerical hydrodynamic simulations, likely representing the development of hydrodynamic instabilities between the shocked ejecta and the shocked ISM. Lower-resolution (with adaptive mesh) maps of other spectral analysis parameters, such as the temperature of thermal plasma, power law index of synchrotron emission, electron density, ionization timescale, and metal abundances, are also constructed. To study the particle acceleration processes, we extract broad-band spectra from radio to X-ray from a set of small regions along some nonthermal filaments at the forward shock. We then study the azimuthal variation (along these filaments) of the synchrotron spectral index and cut-off frequency, as well as the width of the filaments. The azimuthal dependence of these parameters provides strong constraints on the acceleration mechanism. We conclude that the particle acceleration efficiency is strongly dependent on the obliquity angle between the shock velocity and the upstream magnetic field.

127.09 – SN 1006 From Chandra: High-resolution Radial Profiles of the Ejecta

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We present further early results from a recent Large Project observation of the remnant of SN 1006 with Chandra, where 10 overlapping ACIS fields have created a mosaic with a total exposure time of 700 ks and a minimum of 100 ks at any line-of-sight through the remnant. Chandra's superior spatial resolution combined with the significant depth of exposure throughout SN 1006 allow the study of structures within the ejecta on scales as small as a few arcseconds. Azimuthally-averaged radial profiles from annular regions of 10' in width show variations with radius in the line strengths of silicon, oxygen, and magnesium. At an assumed distance of 2.2 kpc to SN 1006, 10' corresponds to a physical distance of a tenth of a parsec. The line centroids also provide information on the ionization state of the various ejecta products. We map the abundances of various elements using non-equilibrium ionization models, and determine relative abundances of various ejecta products. Combined with the large size of the remnant, this represents by far the most spatially-detailed map of the ejecta in a Type Ia SN. We interpret our results in the context of the stratification layers in the ejecta, which has important implications for the explosion models of Type Ia SNe.

127.10 – Particle Acceleration and Magnetic Fields: Looking at the Northwestern Rim of RCW 86 with Chandra

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Non-thermal X-ray emission has been detected from several young shell-type supernova remnants (SNRs), including RX J1713.7-3946, and Vela Jr. These X-rays are believed to be synchrotron radiation from electrons accelerated to TeV energies at the shocks, interacting with the compressed, and possibly amplified, local magnetic field. Observations of gamma-ray emission from several SNRs in the TeV range confirm that particles are being accelerated to energies approaching the knee of the cosmic ray spectrum in these remnants. However, while it is broadly believed that diffusive shock acceleration (DSA) in SNRs produces the bulk of cosmic rays below 1 PeV, we still lack a detailed understanding of the acceleration process and its effects on the system, such as magnetic field amplification (MFA) and modifications to hydrodynamic evolution. I will report on our recent observations of the NW rim of SNR RCW 86 with the Chandra X-ray Observatory. This deep look into this SNR allow us to constrain the value of the post-shock magnetic field and the properties of the shock, and hence gain insight into the nature of the cosmic ray acceleration mechanism.

127.11 – X-ray Emission from the Galactic Supernova Remnant G272.2-3.2

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We present analysis of Chandra X-ray Observatory data detailing a galactic supernova remnant, G272.2-3.2. A clear shell of emission has been resolved for the first time as a series of filaments and knots around the entire rim of the remnant. Spectral analysis of these features show that they are consistent with shock heating of interstellar material in a clumpy medium. Spatially separated from this shell we see a central diffuse region dominated by harder, hotter emission. Spatial spectroscopy shows a clear enhancement of metals consistent with a Type Ia explosion, namely S, Si, and Fe. We find no clear evidence for a compact object or pulsar wind nebula and argue for a Type Ia origin. Consideration of the ionization timescales suggest an age of 8700 years for G272.2-3.2.

127.12 – Unraveling the Origin of Overionized Plasma in the Galactic Supernova Remnant W49B

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In this presentation, I present maps of overionized plasma in the Galactic supernova remnant (SNR) W49B based on a recent 220 ks Chandra Advanced CCD Imaging Spectrometer observation. Overionized plasmas (those where ions are stripped of more electrons than they should be for a given electron temperature) have been found recently in several SNRs, and the physical origin of the rapid cooling necessary to produce them remains uncertain. To assess the cooling scenario responsible for overionization, we performed a spatially-resolved spectroscopic analysis of W49B, measuring the electron temperature by modeling the bremsstrahlung continuum and comparing it to the temperature given by the flux ratio of He-like to H-like lines of sulfur, argon, and calcium. Using these results, we find that the west region of W49B is the most overionized, with a gradient of increasing overionization from East to West. As the ejecta expansion is impeded by molecular material in the east but not in the west, our overionization maps suggest the dominant cooling mechanism is adiabatic expansion of the hot plasma instead of thermal conduction. Furthermore, we find calcium has the greatest degree of overionization relative to argon and sulfur; this result arises because calcium has a longer recombination timescale. Thus, we caution that measurement of overionization is dependent on which elements one employs in their line ratio analysis.

127.13 – G306.3-0.9: A Newly Discovered Young Galactic Supernova Remnant

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We present X-ray and radio observations of the new Galactic supernova remnant (SNR) G306.3-0.9, recently discovered by Swift. Chandra imaging reveals a complex morphology, dominated by a bright shock. The X-ray spectrum is broadly consistent with a young SNR in the Sedov phase, implying an age of 2500 yr for a distance of 8 kpc, plausibly identifying this as one of the 20 youngest Galactic SNRs. Australia Telescope Compact Array (ATCA) imaging reveals a prominent ridge of radio emission that correlates with the X-ray emission. We find a flux density of ~ 160 mJy at 1 GHz, which is the lowest radio flux recorded for a Galactic SNR to date. The remnant is also detected at 24 microns, indicating the presence of irradiated warm dust. The data reveal no compelling evidence for the presence of a compact stellar remnant.

127.14 – The Complex Region Containing the Gamma-cygni Supernova Remnant

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The gamma Cygni supernova remnant is studied with new radio continuum and HI observations and archival ROSAT and CHANDRA X-ray observations. The atomic hydrogen (HI) line and radio continuum data yield a new HI absorption distance to gamma Cygni (G78.2+2.1) with a corresponding HI column density. New x-ray images of the region including the supernova remnant G78.2+2.1 are constructed from the ROSAT survey and from the Chandra and ROSAT pointed observations. The association of the non-thermal radio emission from the remnant with the corresponding X-ray shells is discussed. The high (spectral and spatial) resolution Chandra data is used to study the nature of G78.2 and of a second overlapping X-ray shell, previously believed to be associated with G78.2+2.1, but now shown to be a foreground object. We also examine compact and extended sources of hard x-ray emission previously thought to coincide with the remnant.

127.15 – Particle Acceleration and Magnetic Field Amplification at Non-relativistic Collisionless Shocks

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We investigate the dynamics of non-relativistic, collisionless shocks by using unprecedentedly large 2D and 3D hybrid (kinetic ions – fluid electrons) simulations. We find that, at parallel shocks, ions are efficiently accelerated via first-order Fermi mechanism; the current driven by the energetic particles propagating into the upstream medium excites plasma instabilities that strongly perturb the initial electromagnetic configuration. In particular, the filamentation instability produces tubular, underdense, magnetic-field-depleted cavities, in which accelerated particles are channeled. These structures grow while being advected with the fluid, effectively corrugating the shock surface and triggering turbulent motions in the downstream. The net result is a marked increase of the magnetic field, both ahead and behind the shock, in agreement with the high levels of magnetization inferred at the blast waves of young supernova remnants. We also discuss the dependence of the ion acceleration efficiency on the orientation and on the strength of the upstream magnetic field, finding that ions are preferentially accelerated at parallel, fast shocks (i.e., shocks propagating along the initial magnetic field, with velocities much larger than the Alfvén speed).

127.16 – The Gamma-Ray Spectra of Supernova Remnants Arising from SNe of Various Types

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Supernovae (SNe) are generally classified into Type I and Type II. Most SNe, including all those of Type II and Ib/c, arise from the core-collapse of massive stars. During their lifetime, mass-loss from these stars considerably modifies the medium around the stars. When the stars explode as SNe, the resulting shock wave will expand in this wind-modified medium, and the gamma-ray spectra are due to particle acceleration in this medium. In contrast, Type Ia SNe will expand in a relatively uniform medium, but the dynamics are different from those of core-collapse SNe. In this work we compute the spectra of accelerated particles, and the surface brightness distribution at very high energies, for SNRs of various types. We use high-resolution numerical simulations to study the expansion of the SN shock wave in the complicated medium; consider transport of frozen-in magnetic field by the plasma flow within the remnant; calculate cosmic-ray acceleration by solving the cosmic-ray transport equation in the test particle limit; include contributions from both forward and reverse shocks; and trace escaped particles out to about 50 SNR radii. We find that the complex environment, the reverse shock, and plasma-flow profiles all contribute to shaping the particle spectra. Our results show softer spectra for young supernova remnants that are consistent with recent results from Fermi and ground-based telescope arrays.

127.17 – Energetic Supernovae from the Cosmic Dawn

Ke-Jung Chen¹

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We present the results from our 3D supernova simulations by using CASTRO, a new radiation-hydrodynamics code. The first generation of stars in the universe ended the cosmic dark age by shining the first light. But what was the fate of these stars? Based on the stellar evolution models, the fate of stars depends on their masses. Modern cosmological simulations suggest that the first stars could be very massive, with a typical mass scale over 50 solar masses. We look for the possible supernovae from the death of the first stars with masses over 50 solar masses. Besides the iron-core collapse supernovae, we find energetic thermonuclear supernovae, including two types of pair-instability supernovae and one type of general-relativity instability supernovae. Our models capture all explosive burning and follow the explosion until the shock breaks out from the stellar surface. We will discuss the energetics, nucleosynthesis, and possible observational signatures for these primordial supernovae that will be the prime targets for future large telescopes such as the James Webb Space Telescope (JWST).

127.18 – VERITAS Studies of the TeV Emission from MGRO J1908+06/HESS J1908+063

Daniel D. Gall¹

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Contributing teams: VERITAS Collaboration

We will report on recent observations of complex TeV emission from MGRO J1908+06/HESS J1908+063. This extended source is located on the galactic plane at a longitude of 40.4 degrees and has a hard spectrum with an index of ~ 2.1 . The TeV source has been attributed to the pulsar wind nebula of the nearby Fermi-LAT pulsar PSR J1907+0602. Initial VERITAS observations of the TeV gamma-ray source MGRO J1908+06/HESS J1908+063 were taken during July 2007 and May-June 2008. Further observations with VERITAS, obtained between 2009-2012, have been studied to determine the morphology of the TeV emission extending up to 30 TeV. The analysis of these VERITAS observations will be presented as well as some discussion of the implications on the emission scenario.

127.19 – Core Compactness of Progenitors

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The compactness of the core of a pre-supernova star is one of the important unexplored issues in progenitor evolution. Recent studies have found the core compactness to be varying non-monotonically as a function of ZAMS mass. In this work we have calculated a large grid of 1D full stellar and naked C/O core models using the implicit hydrodynamic code KEPLER and the open source stellar evolution code MESA, in order to gain a better insight in core compactness' dependence on the stellar mass and convection physics. We find the complicated evolution during C, O and Si burning phases act as the main cause of the non-monotonic variation of compactness, and the whole compactness curve as a function of mass to be quite dependent on the treatment of semiconvection. We

also conclude that the C/O core mass is the main discriminant of pre-supernova structure.

127.21 – On Poynting-Flux-Driven Bubbles and Shocks Around Merging NS/Magnetar Binaries and Implications for SGRBs

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Merging binaries of compact relativistic objects (neutron stars and black holes) are thought to be progenitors of short gamma-ray bursts and sources of gravitational waves, hence their study is of great importance for astrophysics. Because of the strong magnetic field of one or both binary members and high orbital frequencies, these binaries are strong sources of energy in the form of Poynting flux (e.g., magnetic-field-dominated outflows, relativistic leptonic winds, electromagnetic and plasma waves). The steady injection of energy by the binary forms a bubble (or a cavity) filled with matter with the relativistic equation of state, which pushes on the surrounding plasma and can drive a shock wave in it. Unlike the Sedov-von Neumann-Taylor blast wave solution for a point-like explosion, the shock wave here is continuously driven by the ever-increasing pressure inside the bubble. We calculate from the first principles the dynamics and evolution of the bubble and the shock surrounding it and predict that such systems can be observed as radio sources a few hours before and after the merger. At much later times, the shock is expected to settle onto the Sedov-von Neumann-Taylor solution, thus resembling an explosion.

127.22 – Are Short Bursts with Extended Duration Emission Powered by Magnetars?

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The standard model for short duration GRBs involves the merger of a compact binary system resulting in a black hole which accretes for a very brief period of time. While this model can explain a brief emission spike, some short GRBs have an extended period of emission which can last for about 100 seconds in the rest-frame. We investigate whether this extended emission could be powered by the spin-down of a magnetar formed during the merger event and compare the derived magnetar properties with those for other GRBs.

127.23 – Gamma-Ray Bursts: Pulses and Populations

Thomas J. Loredo¹, Jon E. Hakkila², Mary Beth Broadbent³, Ira M. Wasserman¹, Robert L. Wolpert³

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We describe ongoing work on two projects that are enabling more thorough and accurate use of archival BATSE data for elucidating the nature of GRB sources; the methods and tools we are developing will also be valuable for analyzing data from other missions. The first project addresses modeling the spectro-temporal behavior of prompt gamma ray emission from GRBs by modeling gamma ray count and event data with a population of pulses, with the population drawn from one or more families of single-pulse kernels. Our approach is built on a multilevel nonparametric probabilistic framework we have dubbed 'Bayesian droplets,' and offers several important advances over previous pulse decomposition approaches: (1) It works in the pulse-confusion regime, quantifying uncertainty in the number, locations, and shapes of pulses, even when there is strong overlap. (2) It can self-consistently model pulse behavior across multiple spectral bands. (3) It readily handles a variety of spatio-temporal kernel shapes. (4) It reifies the idea of a burst as a population of pulses, enabling explicit modeling and estimation of the pulse population distribution. We describe the framework and present analyses of prototypical simple and complex GRB light curves. The second project aims to enable accurate demographic modeling of GRBs using the BATSE catalog. We present new calculations of the BATSE sky exposure, encompassing the full duration of the BATSE catalog for the first time, with many improvements over the currently available exposure map. A similar calculation of the detection efficiency is in progress. We also describe public Python software enabling access and accurate modeling of BATSE GRB data. The software enables demographic studies (e.g., modeling log N - log S distributions) with accurate accounting of both selection effects and measurement errors. It also enables spectro-temporal modeling of detailed data from individual GRBs. These projects are supported by NASA through the AISR and ADAP programs.

127.24 – GCN/TAN -- Current and Future Functionality

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The Gamma-ray Coordinates Network / Transient Astronomy Network (GCN/TAN) has been operating for 20 years. It collects all the detections of GRBs and other astrophysical transients (positions and times) and distributes that information to nearly all the observers and instruments around the world; all done automatically, with minimal time delays (seconds in most cases). In recent years several non-GRB-producing data streams have been added (gravitational lensing events from MOA and flares from AGN, novae, flare stars, etc from the Fermi, MAXI and Swift missions). And to facilitate cross-instrument temporal and spatial correlations, GCN/TAN has been modified (a) to identify in real time these correlations as the notices are distributed, and (b) producing 'sub-threshold' streams from the Swift and INTEGRAL missions. The later allows other instruments (ground and flight; eg ICECUBE, and in the future aLIGO) to make correlations that would then raise the confidence level of these sub-threshold detections. These temporal/spatial correlations will be expanded to include mission-based data sets that are not real-time (ie hours to days delayed). Three VOEvent servers have been added to distribute the entire set of GCN/TAN notices in that format and method.

127.25 – A Correlation Between Intrinsic Luminosity and Average Decay Rate in GRB Afterglows

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We will present recent efforts to characterize and understand the origin of the correlation between the early luminosity of GRB afterglows and the rate at which they decay, discovered by Oates et al. 2012 in the UV/optical afterglows observed by Swift. The study has been expanded to the X-ray afterglows observed by Swift-XRT, which demonstrate more complex temporal structures than the optical light curves, reflecting contributions from multiple emission components, and find that the correlation is also significant in the X-ray. We explore whether the origin of the correlation is geometrical - due to some component of the observing perspective, physical - an intrinsic property of the GRB jet, or an observing bias - that may explain some of the wide variation in GRB light curves.

127.26 – Pulsars in the High Energy and Early Universe

John Middleditch¹, Andrea C. Schmidt^{1, 2}, John Singleton^{1, 3}, Houshang Ardavan⁴, Arzhang Ardavan⁵

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The mechanism of polarization currents excited supraluminally (updated faster than c) by rotating neutron star magnetospheres (SLIP) can be used to explain the means by which supernova progenitors are disrupted, including the details of SN 1987A. At radii of a few times that of the light cylinder the effect helps to lift material away from the core. At much greater radii, the paths from current-containing annuli clear the stellar core on the way to the poles, where the concentration of the effects results in highly collimated pulsar-driven jets with velocities in excess of $0.95c$, and element transmutation via the r-process. SLIP also accounts for the anomalous dimming of SNe Ia at cosmological distances, jets from Sco X-1 and SS 433, the lack/presence of pulsations from the high/low luminosity low mass X-ray binaries, long/short gamma-ray bursts, and predicts that their afterglows are the pulsed optical-/near-infrared emission associated with the pulsars. Pulsar-driven jets from the SNe of the first stars may allow galaxies to form without the need for dark matter. SLIP may also account for the TeV e^+/e^- results from PAMELA and ATIC, the WMAP 'haze'/Fermi 'bubbles', and the spectrum of the nine Fermi-LAT pulsars with radio observations, over 16-18 orders of magnitude of frequency with minimal adjustable parameters. With parameters extracted from the broadband fits, we have calculated values for the number density of electrons and the magnetic field, B , at the emitting region and derived some systematic properties of these pulsars' plasma atmospheres.

127.27 – A Four-Year Fermi LAT Survey of Terrestrial Gamma-ray Flashes

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Contributing teams: Fermi LAT Collaboration

The Fermi LAT regularly detects Terrestrial Gamma-ray Flashes (TGFs) during its nominal astrophysical sky-survey observing program. Because of the LAT's flexible trigger logic, TGF emissions at and above 10 MeV are detected with high sensitivity despite their having arrived from outside the instrument's field of view. Bright TGFs can be imaged with good accuracy for comparison with VLF geolocations. A deep search of the first four years of LAT data reveals more than 300 TGFs with hard gamma-ray emission, many of which were independently detected by Fermi GBM. Here we present a summary of the spectral, temporal, diurnal, and geographic features of this sample of high-energy TGFs.

127.28 – Gamma-ray and X-ray Observations Towards the Gamma-Cygni Supernova Remnant

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Contributing teams: VERITAS Collaboration

We report on observations of the source VER J2019+407 towards the Gamma-Cygni supernova remnant. Very high energy (> 320 GeV) gamma-ray emission from the source was detected by the VERITAS observatory, an array of four 12-meter imaging atmospheric Cherenkov telescopes based near Tucson, Arizona. The proximity of this source to a diffuse region of gamma-ray emission detected by the Fermi Space Telescope increases its significance, and may suggest a connection between the two. To further investigate the properties of VER J2019+407, we have obtained a 50 ks Chandra observation of this region. Analysis of the Chandra data, and implications for the gamma-ray source, will be presented.

127.29 – Exploring the X-ray Morphology of the Supernova Remnant Kes 27 using Numerical Simulations

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Kesteven 27 is a member of the class of thermal composite or mixed-morphology remnants, which can show thermal X-ray emission extending all the way in towards the center. The Chandra image shows two incomplete shell-like features in the north-eastern half, with brightness fading towards the southwest. The X-ray and radio structure led Chen et al. (2008) to suggest that the morphology represents a supernova remnant expanding in a windblown bubble. The two X-ray rings represent the outer shock of the supernova remnant, and a reflected shock arising from collision with a dense shell. Using numerical simulations followed by a computation of the X-ray emission, we explore this possibility. Our initial modeling suggests that the scenario discussed by Chen et al. (2008) may not work. We suggest and discuss modifications to this scenario that may be able to reproduce the observed morphology, and the implications for thermal composite remnants.

128 – Tidal Disruptions

128.01 – Jetted Tidal Disruption Gone MAD: Case of Dynamically Important Magnetic Field Near the Black Hole in Sw J1644+57

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It is likely that the unusual gamma-ray/X-ray/radio transient Swift J1644+57 was produced by a collimated relativistic jet formed in the aftermath of a tidal disruption (TD) of a star by a massive black hole (BH). Some of the properties of the event are, however, difficult to explain within the TD scenario: (1) extreme flaring and 'plateau' shape of the gamma-ray/X-ray light curve during the first 10 days after the gamma-ray trigger; (2) unexpected rebrightening of the forward shock radio emission months after trigger; (3) no obvious evidence for jet precession, despite misalignment typically expected between the angular momentum of the accretion disk and BH; (4) recent abrupt shut-off in jet X-ray emission after 1.5 years. Here we show that all of these seemingly disparate mysteries are naturally resolved by one assumption: the presence of strong magnetic flux Φ threading the BH. Initially, Φ is weak relative to high fall-back mass accretion rate, \dot{M} , and the disk and jets precess about the BH axis = our line of sight. As \dot{M} drops, Φ becomes dynamically important and leads to a magnetically-arrested disk (MAD). MAD naturally aligns disk and jet axis along the BH spin axis, but only after a violent rearrangement phase (jet wobbling). This explains the erratic light curve at early times and the lack of precession at later times. We use our model for Swift J1644+57 to constrain BH and disrupted star properties, finding that a solar-mass main sequence star disrupted by a relatively low mass, $M \sim 10^5 - 10^6 M_{\text{sun}}$, BH is consistent with the data, while a WD disruption (though still possible) is disfavored. The magnetic flux required to power Swift J1644+57 is too large to be supplied by the star itself, but it could be collected from a quiescent 'fossil' accretion disk present in the galactic nucleus prior to the TD. The presence (lack of) of such a fossil disk could be a deciding factor in what TD events are accompanied by powerful jets.

128.02 – The Rise and Fall of Swift J164449.3+573451

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Contributing teams: Swift XRT Team

Swift J164449.3+573451 is the most intensively studied tidal disruption candidate. Following its discovery by the Swift satellite on March 28, 2011, Swift observed it on a nearly daily basis for over 18 months, obtaining over 2 million seconds of accumulated exposure and documenting its highly variable X-ray emission, its overall decline beginning about 10 days after discovery, and its sudden tumoff in August 2012. I will present an updated X-ray light curve and will discuss its implications.

128.03 – Simulating Tidal Disruptions of Stars on Bound Orbits Around Supermassive Black Holes

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A star orbiting a supermassive black hole (SMBH) is disrupted when its distance from the hole is smaller than the tidal radius. Many previous studies focused on studying tidal disruption of stars on parabolic orbits using Newtonian mechanics. Such disruptions, however, can also happen near the innermost stable circular orbit of the hole, where general relativity (GR) plays an important role. Also it is likely that such stars can be disrupted on bound orbits around holes, which will produce distinctly different observational signatures from the standard picture. The orbits of debris have apsidal and Lense-Thirring precessions due to GR effects. The pattern of debris returning to the hole and the structure of the accretion disk formed by these materials also highly depend on the black hole spin and orbital parameters. We performed a three-dimensional GR particle simulation on tidal disruptions of stars on such orbits near Schwarzschild and Kerr SMBHs, and investigated interesting cases where the simulated results can be used to test general relativity and constrain SMBH parameters.

129 – X-ray Binaries

129.01 – NuSTAR Observations of the Be/X-ray Binary GRO J1008-57 in Outburst

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Contributing teams: NuSTAR Science Team

GRO J1008-57 is an HMXB that exhibits regular outbursts due to orbitally-driven accretion onto the neutron star from the Be companion. Spectral analysis of previous bursts have suggested the existence of a cyclotron resonant scattering feature at 88 keV, which, if confirmed as the fundamental line, would indicate the presence of one of the most highly-magnetized accreting neutron stars. In November 2012, GRO J1008 produced a Type II ('giant') burst with peak flux near 1 Crab. NuSTAR observed the outburst for 12 ksec near the peak of emission. We present spectral and timing analysis of GRO J1008 over NuSTAR's 3-79 keV energy band. Considering that the putative 88 keV line could be a harmonic rather than the fundamental, we search for cyclotron lines in the NuSTAR band and discuss implications for models of the system's magnetic field.

129.02 – Angular Momentum Transport in Accreting White Dwarfs: Uniform or Differential Rotation?

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We probe the basic nature of angular momentum transport inside accreting white dwarfs, including all suggested hydrodynamic mechanisms, e.g., Kelvin-Helmholtz, baroclinic, and Goldreich-Schubert-Fricke instabilities, for this transport and deferring the inclusion of magnetic fields to the next paper in the series. We show that the two remarkably different outcomes for the internal rotation profile found in the previous literature, viz, (a) strong differential rotation and (b) uniform or near-uniform rotation, are both possible under these circumstances, depending on what regime of Richardson number, Ri , one operates in. Small values of Ri lead to strong differential rotation, and large values of Ri to uniform rotation. We demonstrate that both regimes of operation are possible, contrary to previous conclusions. Thus, the notion of mutual exclusivity of the above two possibilities is incorrect, and both should exist in nature, at least in principle. We explore the circumstances which may decide which regime a given white dwarf will go into, and consequences for accreting white-dwarf binaries. We discuss how the inclusion of magnetic fields is likely to modify our results.

129.03 – Observational Evidence for Intermediate Mass Black Holes: The State Transitions of ESO 243-41 HLX-1

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Ultra-luminous X-ray source are off-nuclear extragalactic X-ray sources that exceed the Eddington luminosity for a stellar-mass black hole. I will focus on the study of the ultra-luminous X-ray source ESO 243-49 HLX-1 with $>10^{42}$ erg/s, which is the best intermediate mass black hole candidate currently known. Those black holes could play a key role in the formation of supermassive black holes. The source HLX-1 was observed in two main, well defined X-ray spectral states that are consistent with the thermal and the hard states, reminiscent of Galactic stellar-mass black hole binaries. Both beamed emission and super-accretion are thus unlikely, leading to a constraint of the mass of $>9000 M_{\text{sun}}$. This is the strongest argument to claim the existence of a bona fide intermediate mass black hole.

130 – Public Outreach|Public Outreach|Public Outreach|Public Outreach

130.01 – 'Here, There, and Everywhere': Connecting Science Across The Universe

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'Here, There, and Everywhere' (HTE) is a program -- conceived and developed by the Chandra Education and Public Outreach group -- that consists of a series of exhibitions, posters, and supporting hands-on activities that utilize analogies in the teaching of science, engineering, and technology to provide multi-generational and family-friendly content in English and Spanish to small community centers, libraries, under-resourced small science centers. The purpose of the program is to connect crosscutting science content (in Earth, atmospheric and planetary sciences and astrophysics) with everyday phenomena, helping to demonstrate the universality of physical laws and the connection between our everyday world and the universe as a whole to members of the public who may not identify strongly with science. The program utilizes multimodal content delivery (physical exhibits and handouts, interpretive stations, facilitated activities for educators as well as online materials) hosted by under-served locations as identified by previous partnerships as well as through advertisement of opportunities.

130.02 – Astrobites: The Astro-ph Reader's Digest For Undergraduates

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Contributing teams: Astrobites Team

Astrobites (<http://astrobites.com>) is a daily blog aimed primarily at undergraduates interested in astrophysical research and written by a team of graduate students located at diverse institutions around the world. Nearly every day we present a journal article recently posted to astro-ph in a brief format that is accessible to anyone with a general background in the physical sciences. In addition to summarizing new work, Astrobites provides valuable context for readers not yet familiar with the astrophysical literature. Special posts offer career guidance for undergraduates (e.g. applying for an NSF graduate fellowship) and describe personal experiences (e.g. attending an astronomy summer school). We will discuss the Astrobites format and recent readership statistics, as well as potential methods for incorporating Astrobites into the classroom.

200 – Missions and Instruments

200.01 – Probing Temperatures in the Extreme Colliding-Wind Binary Eta Carinae using Iron-Line Diagnostics

Jean-Christophe Leyder^{1, 2}

1. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 2. Universities Space Research Association, Columbia, MD, United States.

Contributing teams: *Eta Carinae Team*

Eta Carinae, one of the most peculiar objects in our Galaxy, was the second brightest object in the sky during its eruption in 1843. The large quantities of matter that were ejected at that time are now forming an extended nebula, while Eta Car is still ejecting matter through energetic stellar winds. Eta Car is a colliding-wind binary system: the dense stellar wind coming from the massive luminous blue variable primary star collides with the higher-velocity, lower-density wind from the hotter and luminous (and otherwise unseen) companion star in a highly eccentric orbit. Monitoring observations in the radio, UV, optical, and X-ray domains all indicate an orbital period of 5.5 years. X-ray observations of a colliding-wind binary system such as Eta Carinae provide numerous clues as to the shock physics and mechanisms responsible for particle acceleration and emission in the hydrodynamical shocks that form between the stellar winds. Furthermore, Eta Carinae's long period and high eccentricity provides varying physical conditions, and allow to probe a large parameter space of densities and wind speeds, especially when observing periastron passages where strong variations occur over a short timescale. In my talk, I will present a set of 24 high-resolution X-ray spectra of Eta Carinae obtained by the Chandra satellite, with a particularly detailed coverage around the X-ray minima of 2003.5 and 2009. I will mostly focus on the variations and peculiarities observed in the Fe K line region. Indeed, at energies around 7 keV, absorption becomes much less important, and the temperatures probed are much higher than what can be done using the Fe triplet around 1 keV. The relative intensities of the Fe XXV and Fe XXVI lines provide a very useful diagnostic of the temperature in the apex of the shock, one of the best approaches to obtain observational constraints. They appear to vary along the orbital phase with a repeatable pattern, and I will suggest a likely interpretation. Furthermore, the unexpected presence of a variable 'red wing' in the profile of the Fe XXV triplet is puzzling, and I will discuss possible explanations.

200.02 – The Fermi Large Area Telescope as a Cosmic-Ray Detector

Maria Elena Monzani¹

1. SLAC National Accelerator Laboratory, Menlo Park, CA, United States.

Contributing teams: *Fermi-LAT Collaboration*

The Fermi Gamma-ray Space Telescope is a space observatory aimed at studying the high-energy Universe. The main instrument onboard Fermi, the Large Area Telescope (LAT), was designed as a pair-conversion gamma-ray telescope, but has also been successfully used to measure the inclusive spectrum of electrons plus positrons up to 1 TeV and in searching for anisotropies in the incoming direction of electrons and positrons. In addition, a measurement of cosmic-ray positron-only and electron-only spectra for energies between 20 GeV and 200 GeV was accomplished by using the Earth's magnetic field as a charge separator. I will describe the challenges involved in using the LAT as a cosmic-ray detector and review our most recent results in this field, together with their interpretation.

200.03 – High-Energy Astrophysics with the High Altitude Water Cherenkov (HAWC) Observatory

John Pretz¹

1. Physics Division, Los Alamos National Lab, Los Alamos, NM, United States.

Contributing teams: *HAWC Collaboration*

The High Altitude Water Cherenkov (HAWC) observatory, under construction at Sierra Negra in the state of Puebla, Mexico, consists of a 22500 square meter area of water Cherenkov detectors: water tanks instrumented with light-sensitive photomultiplier tubes. The experiment is used to detect energetic secondary particles reaching the ground when a 50 GeV to 100 TeV cosmic ray or gamma ray interacts in the atmosphere above the experiment. By timing the arrival of particles on the ground, the direction of the original primary particle may be resolved with an error of between 1.0 (50 GeV) and 0.1 (10 TeV) degrees. Gamma-ray primaries may be distinguished from cosmic ray background by identifying the penetrating particles characteristic of a hadronic particle shower. The instrument is 10% complete and is performing as expected, with 30% of the channels anticipated by the summer of 2013. HAWC will complement existing Imaging Atmospheric Cherenkov Telescopes and space-based gamma-ray telescopes with its extreme high-energy sensitivity and its large field-of-view. The observatory will be used to study particle acceleration in Pulsar Wind Nebulae, Supernova Remnants, Active Galactic Nuclei and Gamma-ray Bursts. Additionally, the instrument can be used to probe dark matter annihilation in halo and sub-halos of the galaxy. We will present the sensitivity of the HAWC instrument in the context of the main science objectives. We will also present the status of the deployment including first data from the instrument and prospects for the future.

200.04 – CTA - A New Observatory for Very High Energy Gamma-Ray Observations

David A. Williams¹

1. UC, Santa Cruz, Santa Cruz, CA, United States.

Contributing teams: *Cherenkov Telescope Array*

The Cherenkov Telescope Array (CTA) will be a new observatory for the study of very high energy (VHE) gamma-ray sources. It seeks to achieve an order of magnitude improvement in sensitivity in the ~30 GeV to ~100 TeV energy band over currently operating instruments (VERITAS, MAGIC, HESS). CTA will shed new light on the high energy extension of the spectra of Fermi sources, probe the known VHE sources with unprecedented sensitivity and angular resolution, and detect hundreds of new sources. The plans for CTA are presented. The presentation focuses on how CTA will be able to address key science topics such as the indirect detection of dark matter, cosmic ray acceleration, and very high-energy gamma-ray production in blazar jets.

200.05 – The ASTRO-H X-ray Observatory

Tadayuki Takahashi¹, Kazuhisa Mitsuda¹, Richard L. Kelley²

1. ISAS/JAXA, Sagami-hara, Japan. 2. NASA/GSFC, Greenbelt, MD, United States.

Contributing teams: *ASTRO-H Team*

The joint JAXA/NASA ASTRO-H mission is the sixth in a series of highly successful X-ray missions initiated by the Institute of Space and Astronautical Science (ISAS), to be launched in 2015. ASTRO-H will investigate the physics of the high-energy universe via a suite of four instruments, covering a very wide

energy range, from 0.3 keV to 600 keV. These instruments include a high-resolution, high-throughput spectrometer sensitive over 0.3-12 keV with high spectral resolution of 7 eV (FWHM), enabled by a micro-calorimeter array located in the focal plane of thin-foil X-ray optics; hard X-ray imaging spectrometers covering 5-80 keV, located in the focal plane of multilayer-coated, focusing hard X-ray mirrors; a wide-field imaging spectrometer sensitive over 0.4-12 keV, with an X-ray CCD camera in the focal plane of a soft X-ray telescope; and a non-focusing Compton-camera type soft gamma-ray detector, sensitive in the 40-600 keV band. The simultaneous broad bandpass, coupled with high spectral resolution, will enable the pursuit of a wide variety of important science themes. The high spectral resolution brought by the micro-calorimeter array will open up a full range of plasma diagnostics and kinematic studies of X-ray emitting gas for thousands of targets, both Galactic and extragalactic. The ASTRO-H mission objectives are: to determine the evolution of yet-unknown obscured supermassive black holes (SMBHs) in Active Galactic Nuclei (AGN); to trace the growth history of the largest structures in the Universe; to trace the chemical evolution of the universe; to probe feedback from the growth of supermassive black holes onto their galaxy and cluster environments; to provide insights into the behavior of material in extreme gravitational fields; to determine the spin of black holes and the equation of state of neutron stars; to trace particle acceleration structures in clusters of galaxies and SNRs; and to investigate the detailed physics of astrophysical jets.

200.06 – The Large Observatory For X-ray Timing (LOFT): The ESA Mission and Proposed US Contributions

Paul S. Ray¹, Marco Feroci², Jan-Willem den Herder³, Enrico Bozzo⁴, Deepto Chakrabarty⁵, Colleen Wilson⁶

1. NRL, Washington, DC, United States. 2. IAPS-INAF, Rome, Italy. 3. SRON, Utrecht, Netherlands. 4. ISDC, Geneva, Switzerland.

5. MIT, Cambridge, MA, United States. 6. NASA/MSFC, Huntsville, AL, United States.

Contributing teams: LOFT Consortium, US-LOFT Collaboration

High-time-resolution X-ray observations of compact objects provide direct access to strong-field gravity, to the equation of state of ultradense matter and to black hole masses and spins. A 10 m²-class instrument in combination with good spectral resolution is required to exploit the relevant diagnostics and answer fundamental questions about matter under extreme conditions. The Large Observatory For X-ray Timing (LOFT), selected by ESA as one of the four Cosmic Vision M3 candidate missions to undergo an assessment phase, will revolutionize the study of collapsed objects in our Galaxy and of the brightest supermassive black holes in active galactic nuclei. Thanks to an innovative design and the development of large-area monolithic silicon drift detectors, the Large Area Detector (LAD) on board LOFT will achieve an effective area of over 10 m² (more than an order of magnitude larger than any spaceborne predecessor) in the 2–30 keV range (up to 50 keV in expanded mode), yet still fits in a conventional platform and medium-class launcher. With this large area and a spectral resolution of <260 eV, LOFT will yield unprecedented information on strongly curved spacetimes and matter under extreme conditions of pressure and magnetic field strength. A second instrument onboard LOFT, the Wide Field Monitor (WFM), will discover and localize X-ray transients and impulsive events and monitor spectral state changes with unprecedented sensitivity and coverage. Through the LOFT Burst Alert System (LBAS), locations and times of impulsive events discovered by the WFM will be relayed to the ground within about 30 seconds. In this talk, we will present an overview of the design and status of the LOFT mission and describe the proposed US contributions currently under evaluation by NASA. NRL participation in LOFT is funded by NASA.

200.07 – This Is Not Your Advisor's CIAO

Jonathan C. McDowell¹, Douglas J. Burke¹, Antonella Fruscione¹, Aneta Siemiginowska¹

1. Harvard-Smithsonian CfA, Cambridge, MA, United States.

Contributing teams: Chandra X-ray Center CIAO Team

As the Chandra mission continues, the CIAO analysis system continues to evolve. We will discuss the latest version of CIAO emphasizing useful features added in recent years which may be unfamiliar to long-time users. These features lie in two main areas. First, we have scripts to wrap up the most common existing steps in data reduction and analysis to make things simpler for users - these are aimed at making X-ray astronomy accessible to non-specialists, but provide enough adjustable parameters to make them useful to experienced X-ray astronomers. Secondly, we have added new technical capabilities for advanced analysis, including support for overlapping observations ('merging' without actually merging files), improved PSF capabilities following the retirement of mkpsf, better location of grating data zero order, Markov Chain Monte Carlo (MCMC) analysis with Sherpa, and integrating CIAO into Python-based analysis systems. CIAO scientists will be available during the meeting to discuss these new features, provide advice on Chandra analysis and discuss how our changing understanding of the spacecraft and instruments impacts Chandra data reduction.

200.08 – Modeling Non-Equilibrium Collisional Plasmas with AtomDB

Adam Foster¹, Hiroya Yamaguchi¹, Randall K. Smith¹, Nancy S. Brickhouse¹, Li Ji², Tim Kallman³, Joern Wilms⁴

1. Harvard Smithsonian, CfA, Cambridge, MA, United States. 2. Purple Mountain Observatory, Nanjing, Jiangsu, China. 3. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 4. Universität Erlangen-Nürnberg, Erlangen, Bavaria, Germany.

Collisionally ionized plasmas that are in non-equilibrium ionization (NEI) show distinctly different emission from those in equilibrium. Recombining, or overionized, plasmas show significant recombination-driven continuum features, while ionizing plasmas show strong inner-shell emission lines, such as the Iron K α line at 6.4-6.7keV. Existing models in analysis tools such as XSPEC treat only the equilibrium case and part of the ionizing plasma case due to a significant lack of atomic data. We present major updates to the AtomDB database, and new models for use XSPEC, which allow all types of these non-equilibrium plasmas to be modeled in a simple yet accurate fashion. This model has been created using a large amount of data obtained from published sources, supplemented by data we have calculated using the Flexible Atomic Code where required. We identify the spectral features that have been seen and can now be modeled using this data for existing missions as well as Astro-H. We also revisit archival data where recombining plasma emission has previously been identified.

200.09 – The High Resolution Microcalorimeter Soft X-ray Spectrometer for the Astro-H Mission

Richard L. Kelley¹, Kazuhisa Mitsuda²

1. NASA/GSFC, Greenbelt, MD, United States. 2. ISAS/JAXA, Sagami-hara, Japan.

Contributing teams: International SXS Team

We are developing the Soft X-Ray Spectrometer (SXS) for the JAXA Astro-H mission. The instrument is based on a 36-pixel array of semiconductor micro calorimeters that provides high spectral resolution over the 0.3-12 keV energy band at the focus of a high throughput, grazing-incidence x-ray mirror, giving a 3 x 3 arcmin field of view and more than 200 cm² of collecting area at 6 keV. The instrument is a collaboration between the JAXA Institute of Space and Astronautical Science and their partners in Japan, the NASA/Goddard Space Flight Center, the University of Wisconsin, the Space Research Organization of the Netherlands, and Geneva University. The principal components of the spectrometer are the microcalorimeter detector system, low-temperature anticoincidence detector, 3-stage ADR and dewar. The dewar is a long-life, hybrid design with a superfluid helium cryostat, Joule-Thomson cooler, and Stirling coolers. The instrument is capable of achieving 4-5 eV resolution across the array and is designed to operate for at least three years in orbit, and can operate

either without liquid helium or the cooling power of the Joule-Thomson cooler. In this presentation we describe the design and status of the Astro-H/SXS instrument.

201 – NuSTAR

Special Session 12

201.01 – The Nuclear Spectroscopic Telescope Array Mission Overview and First Results

Fiona Harrison¹

1. Caltech, Pasadena, CA, United States.

Contributing teams: NuSTAR Team

The Nuclear Spectroscopic Telescope Array (NuSTAR) mission, launched on 13 June 2012, is the first focusing high-energy X-ray telescope in orbit. NuSTAR operates in the band from 3 – 79 keV, extending the sensitivity of focusing far beyond the ~10 keV high-energy cutoff achieved by all previous X-ray satellites. The inherently low-background associated with concentrating the X-ray light enables NuSTAR to probe the hard X-ray sky with a more than one-hundred-fold improvement in sensitivity over the collimated or coded-mask instruments that have operated in this bandpass. In this talk I will provide an overview of the mission, discuss the in-flight performance, and present some results from observations of Active Galaxies, the Galactic Center, and supernova remnants.

201.02 – The NuSTAR Galactic Binary Program

John Tomsick¹

1. UC Berkeley/SSL, Berkeley, CA, United States.

Contributing teams: NuSTAR Team

NuSTAR, which operates in the 3-79 keV bandpass, is the first hard X-ray focusing telescope. The Galactic binaries program emphasizes two ground-breaking NuSTAR capabilities: the unprecedented sensitivity provided by low background and the advance in energy resolution above 10 keV. For bright X-ray binaries, the program includes studies of cyclotron lines from accreting pulsars (including phase-resolved spectroscopy), reflection components from black hole accretion disks, timing studies of millisecond pulsars, and absorption edges that have the potential to provide a probe of neutron stars undergoing X-ray bursts. For faint X-ray binaries, this is the first time that hard X-ray studies of black hole and neutron star X-ray transients at their lowest mass accretion rates are feasible, providing a new window on accretion processes and emission mechanisms in quiescence. To date, observations of eight X-ray binaries have occurred. In this presentation, we will describe the overall program and highlight results from these early observations.

201.03 – The NuSTAR ULX Program

Dominic Walton¹

1. Caltech, Pasadena, CA, United States.

Contributing teams: NuSTAR Team

The origin of the extreme luminosities displayed by ultraluminous X-ray sources (ULXs) may relate to either super-Eddington accretion or the presence of black holes more massive than standard stellar remnants, e.g. intermediate mass black holes with masses of 100's or 1000's of solar masses. As yet, this origin remains undetermined despite significant observational efforts with soft X-ray missions. The Nuclear Spectroscopic Telescope Array (NuSTAR), launched in June 2012, will probe the hard X-ray emission from ULXs, opening up a new observational window into these enigmatic sources. In combination with coordinated XMM-Newton and Suzaku observations providing simultaneous soft X-ray coverage, these high energy observations will provide unprecedented broadband X-ray spectra for a sample of bright ULXs in the first two years of operation, allowing us to further probe the nature of these sources. Here, we discuss plans and predictions for the NuSTAR ULX program, and present some early results.

201.04 – A Hard X-ray View of Star Formation: NGC 253 in Focus

Ann E. Hornschemeier^{1, 2}, Bret Lehmer², Daniel R. Wik¹, Megan Argo³, Keith Bechtol⁴, Steve Boggs⁵, Finn Christensen⁶, William W. Craig⁵, Charles J. Hailey⁷, Fiona Harrison⁸, Jean-Christophe Leyder¹, Thomas J. Maccarone⁹, Andrew Ptak¹, Daniel Stern¹⁰, Tonia M. Venters¹, Andreas Zezas¹¹

1. NASA GSFC, Greenbelt, MD, United States. 2. Johns Hopkins, Baltimore, MD, United States. 3. ASTRON, Dwingeloo, Netherlands. 4. KICP, University of Chicago, Chicago, IL, United States. 5. UC Berkeley, Berkeley, CA, United States. 6. DTU Space, Lyngby, Denmark. 7. Columbia University, New York, NY, United States. 8. Caltech, Pasadena, CA, United States. 9. Texas Tech University, Lubbock, TX, United States. 10. NASA JPL, Pasadena, CA, United States. 11. Smithsonian Astrophysical Observatory, Cambridge, MA, United States.

Hard X-ray emission from star-forming galaxies arises from a population of neutron stars and stellar-mass black holes, however few starburst galaxies have been detected above 10 keV. We have conducted a NuSTAR-Chandra-VLBA multiwavelength campaign on the nearby starburst galaxy NGC 253 that was designed to (1) sensitively isolate the locations of X-ray binaries, (2) determine the nature of the accreting compact objects via their 0.5-30 keV spectral properties, and (3) identify interesting flaring X-ray/radio sources as they make spectral state transitions due to variability in their accretion. This is the high signal-to-noise pilot for a small program to observe hard X-ray emission from starburst galaxies. We discuss the NGC 253 point source population, spectrum and its implications for our understanding of hard X-ray emission from star forming galaxies in general.

203 – The Fermi Bubbles

Single presenter

203.01 – Fermi Bubbles: Formation Scenarios and Substructure

Douglas P. Finkbeiner¹

1. Harvard Univ., Cambridge, MA, United States.

The Milky Way has gamma-ray lobes extending several kpc above and below the Galactic center, known as the 'Fermi Bubbles.' Although the Galactic center is quiet today, these bubbles are a hint of past AGN activity, a burst of star formation, or some other dramatic energy injection. In the three years since their discovery, they have been modeled analytically and numerically, and additional radio and x-ray data have been obtained, leading to a number of ideas about their origins. I will review the latest data and report on some possible formation scenarios. I will also give an update on our tentative claim last year of a linear jet-like structure within the bubbles (arXiv:1205.5852).

204 – Stellar Compact II: Stellar Mass Black Holes and X-ray Binary Surveys

204.01 – NuSTAR Spectroscopy of the Microquasar GRS 1915+105

Jon M. Miller¹, John Tomsick², Fiona Harrison³

1. Univ. of Michigan, Ann Arbor, MI, United States. 2. University of California at Berkeley, Berkeley, CA, United States. 3. Caltech, Pasadena, CA, United States.

Contributing teams: NuSTAR Team

We present the results of an early observation of the microquasar GRS 1915+105 in a 'plateau' state. This source is well-known as the basis for much work on relativistic jets, disk-jet connections, and comparisons to quasars. In just 16 ks, an excellent spectrum is obtained across the full 3-79 keV band. A strong, broad Fe K line is detected, as well as Fe K edges, and prominent curvature at high energy. The signal to noise at high energy is unprecedented and facilitates strong model constraints. The spectrum can be described extremely well using relativistically-blurred disk reflection models. This source illustrates the ability of NuSTAR to capture definitive reflection spectra of bright Galactic black holes and neutron stars.

204.02 – Accretion Variability in Black-Hole X-ray Binaries: The Optical and X-ray Connection

James F. Steiner¹

1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

Long-term optical and X-ray monitoring of active black-hole X-ray binaries reveals a two week delay in which X-rays lag the optical emission. Motivated by this discovery, we have developed a simple model to describe the mapping between the X-ray and optical emission. This model is comprised of two main variable components: one due to slowly evolving accretion emission, and one due to immediate X-ray reprocessing in the binary system. Under this simple formalism, we can estimate the viscosity parameter, α , in standard disk theory. Further, we find that beyond approximately 20% of the Eddington luminosity, there is a break in the X-ray heating, which we interpret as being due to the flaring in the disk having obscured the companion star from the compact X-ray source.

204.03 – A Statistical Approach to Identifying Compact Objects in X-ray Binaries

Saeqa D. Vrtillek¹

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

A standard approach towards statistical inferences in astronomy has been the application of Principal Components Analysis (PCA) to reduce dimensionality. However, for non-linear distributions this is not always an effective approach. A non-linear technique called 'diffusion maps' (Freeman^{etal}~2009; Richards^{etal}~2009; Lee & Waterman 2010), a robust eigenmode-based framework, allows retention of the full 'connectivity' of the data points. Through this approach we define the highly non-linear geometry of X-ray binaries in a color-color-intensity diagram in an efficient and statistically sound manner providing a broadly applicable means of distinguishing between black holes and neutron stars in Galactic X-ray binaries.

204.04 – XMM-Newton Observations of IC 10 X-1, the Most Massive Known Stellar Black Hole: Eclipse Mapping and 7 mHz QPOs

Tod E. Strohmayer¹, Dheeraj R. Pasham²

1. NASA's GSFC, Greenbelt, MD, United States. 2. University of Maryland, College Park, MD, United States.

IC 10 X-1 is a rare example of an eclipsing black hole/Wolf-Rayet X-ray binary with an orbital period of 34.4 hr. The mass of the black hole is determined dynamically to be 23-35 solar masses, making it the most massive stellar-mass black hole currently known. We present results of XMM-Newton observations which, for the first time, have sampled its X-ray emission for a complete binary orbit. We fully resolve the eclipse and find that it is deep but not total, with an X-ray flux (0.2 - 10 keV) at minimum of about 10% of the off-eclipse average. Interestingly, the eclipse appears moderately asymmetric, with the ingress steeper than the egress. The duration of maximum eclipse is approximately 5.2 hr, or about 15% of the orbital period. The steeper ingress and shallower egress have durations of about 3.3 and 4.6 hr, respectively. The X-ray spectrum shows interesting systematic variations around the orbit which likely reflect the changing optical depth through the Wolf-Rayet companion's wind. For example, the (2 - 10 keV) / (0.2 - 2 keV) hardness ratio peaks during egress, reaches a minimum at a location consistent with superior conjunction of the donor, and then increases again approaching ingress. The emission outside of the eclipse shows substantial aperiodic variability. Moreover, power spectral analysis reveals evidence for a quasiperiodic oscillation (QPO) with a centroid frequency of 6.7 mHz, effectively confirming a marginal QPO detection at the same frequency from an earlier, shorter XMM-Newton observation. The QPO has an amplitude (rms) of approximately 6% (in the full EPIC band-pass) and a quality factor of about 5. We discuss the implications of these observations for the accretion geometry of the source, as well as mass estimates of accreting black holes from X-ray timing measurements.

204.05 – On the Role of the X-ray Corona in Black Hole State Transitions

Ruben C. Reis¹, Jon M. Miller¹, Mark Reynolds¹, Andrew C. Fabian², Dominic Walton³, Edward Cackett⁴, James F. Steiner²

1. university of michigan, ann arbor, MI, United States. 2. Institute of astronomy, Cambridge, cambridgeshire, United Kingdom. 3. caltech, pasadena, CA, United States. 4. wayne state university, detroit, MI, United States.

It has long been speculated that the nature of the hard X-ray corona may be an important second driver of black hole state transitions, in addition to the mass accretion rate through the disk. However, a clear physical picture of coronal changes has not yet emerged. In this talk, I present evidence that both the spectral and timing properties of black hole states may be partially driven by the height of the X-ray corona above the disk, and related changes in how gravitational light bending affects the corona-disk interaction.

204.06 – What's on Tap? The Role of Spin in Compact Objects and Relativistic Jets

Ashley L. King¹, Jon M. Miller¹, Andrew C. Fabian⁴, Christopher S. Reynolds², Dominic Walton³, Kayhan Gultekin¹

1. University of Michigan, Ann Arbor, MI, United States. 2. University of Maryland, College Park, MD, United States. 3. California Institute of Technology, Pasadena, CA, United States. 4. Cambridge University, Cambridge, United Kingdom.

We examine the role of spin in launching jets from compact objects across the mass scale. Our work includes five different Seyfert samples with a total of 39 unique Seyferts, as well as 11 stellar-mass black holes, and 13 neutron stars. We find that when the Seyfert reflection lines are modeled with simple Gaussian

line features, only a slight inverse correlation is found between the line width and radio luminosity. When the Seyfert reflection features are fit with more realistic models, there is a tentative positive correlation between the spin measurement and the radio luminosity. Further, when we include stellar-mass black holes in the sample, to examine the effects across the mass scale, we find an even stronger correlation with spin and radio luminosity per mass, at a marginal significance (2.3 sigma confidence level). Finally, when we include neutron stars, in order to probe lower spin values, we find a strong correlation (4.3 sigma confidence level) between spin and radio luminosity per mass. This suggests that spin does have a role in determining the jet luminosity. In addition, we find a slightly more significant correlation (4.6 sigma confidence level) between spin and radio luminosity per bolometric correlation, using our entire sample of black holes and neutron stars. This points to the idea that mass accretion rate, i.e. bolometric luminosity, is also important in determining the jet luminosity, in addition to spin. The mass accretion and magnetic field strength may be the 'throttle' in these compact systems, to which the Eddington limit and spin may set the maximum jet luminosity that can be achieved.

204.07 – Gemini-GMOS Spectroscopy of X-ray Sources in the Galactic Bulge Survey

Jianfeng Wu¹, Peter G. Jonker^{2, 1}, Manuel Torres^{2, 1}, Jeffrey E. McClintock¹

1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 2. SRON Netherlands Institute for Space Research, Utrecht, Netherlands.

The Galactic Bulge Survey (GBS) is a multiwavelength project with the aim of understanding the population of faint X-ray sources towards the Galactic center. It consists of Chandra and multiwavelength observations of two 6x1 degree strips centered 1.5 degrees above/below the Galactic plane. The main science goals of the GBS include testing binary evolution models by the number counts of detected sources (e.g., CVs and LMXBs), constraining neutron star equation of state and black hole mass function by measuring their masses, and investigating Galactic structure and formation with the spatial distribution of LMXBs. We expect to identify quiescent eclipsing neutron star and black hole LMXBs. For all these goals, it is crucial to classify the X-ray sources via optical spectroscopy. Here we present the time-resolved Gemini-GMOS spectroscopy and the radial velocity analyses of 21 X-ray sources detected by the GBS. Broad (and some double-peaked) H_{alpha} emissions are found for a few sources which makes them likely to be CVs.

204.08 – X-ray Populations in the Norma and Scutum-Crux Spiral Arms

Francesca Fornasini¹, John Tomsick², Farid Rahoui^{6, 7}, Arash Bodaghe², Roman A. Krivonos², Hongjun An⁴, Eric V. Gotthelf³,

Victoria M. Kaspi⁴, Franz E. Bauer⁸, Daniel Stern⁵, Steven E. Boggs²

1. University of California-Berkeley, Berkeley, CA, United States. 2. Space Sciences Laboratory, University of California-Berkeley, Berkeley, CA, United States. 3. Columbia University, New York, NY, United States. 4. McGill University, Montreal, QC, Canada. 5. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States. 6. ESO Garching, Garching, Germany. 7. Harvard University, Cambridge, MA, United States. 8. Pontificia Universidad Catolica de Chile, Santiago, Chile.

In recent years, several surveys aimed at studying stellar X-ray populations have targeted the Galactic center region because it provides a nearby laboratory to explore the dynamics and evolution of galactic nuclei. The distinct environment of the spiral arms provides an important contrast to this region, being generally characterized by a greater abundance of young stellar X-ray sources relative to old ones. We conducted a Chandra Large Program survey of a 2°×0.8° region tangent to the Norma spiral arm to study its X-ray populations, and, in particular, to search for new High Mass X-ray Binaries (HMXBs). This region lies in the direction of the highest concentration of HMXBs and OB associations in the Galaxy. We present a study of ~1000 (>3?) X-ray sources detected in this survey and their cumulative count distribution, comparing it to expectations based on the INTEGRAL Galactic plane survey. In addition, we present results from near-IR spectroscopic follow-up of selected Chandra sources chosen by a combination of spectral hardness, variability, brightness, and counterpart reliability. We find that many of these sources have IR and X-ray properties consistent with those of cataclysmic variables (CVs), and the fact that the majority of X-ray sources in our catalog have similar X-ray spectral properties suggests that, like the Galactic center, the Norma region X-ray populations may be dominated by CVs. Thus far, we have identified six of the selected IR counterparts as massive stars, some of which have X-ray properties consistent with those of HMXBs. Because all these potential HMXBs have relatively faint unabsorbed fluxes (~10⁻¹³ erg/cm²/s in the 2-10 keV band), they could provide significant constraints on the faint end of the HMXB luminosity function.

204.09 – Evolution of X-ray Binaries Across Cosmic Time and Energy Feedback at High Redshift

Tassos Fragos¹

1. Tassos Fragos, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

High redshift galaxies permit the study of the formation and evolution of X-ray binary populations on cosmological timescales, probing a wide range of metallicities and star-formation rates. Here, I will present results from a large scale population synthesis study that models the X-ray binary populations from the first galaxies of the Universe until today. We use as input to our modeling the Millennium II Cosmological Simulation and the updated semi-analytic galaxy catalog by Guo et al. (2011) to self-consistently account for the star formation history and metallicity evolution of the universe. Our modeling, which is constrained by the observed X-ray properties of local galaxies, gives predictions about the global scaling of emission from X-ray binary populations with properties such as star-formation rate and stellar mass, and the evolution of these relations with redshift, as well as the evolution of the galaxy X-ray luminosity function with redshift. Our simulations show that the X-ray luminosity density (X-ray luminosity per unit volume) from X-ray binaries in our Universe today is dominated by low-mass X-ray binaries, and it is only at z>2.5 that high-mass X-ray binaries become dominant. We also find that there is a delay of ~1.1 Gyr between the peak of X-ray emissivity from low-mass X-ray binaries (at z~2.1) and the peak of star-formation rate density (at z~3.1). The peak of the X-ray luminosity from high-mass X-ray binaries (at z~3.9), happens ~0.8 Gyr before the peak of the star-formation rate density, which is due to the metallicity evolution of the Universe. Finally, I will discuss the possible energy feedback of X-ray binaries in the re-ionization and thermal evolution of the Universe at early times, providing prescriptions for the X-ray binary feedback that can be directly incorporated into cosmological simulations.

205 – Accretion, Spin, and Feedback: How are AGN Jets Produced?

205.01 – Relativistic Jets from Accreting Black Holes

Ramesh Narayan¹

1. *Harvard-Smithsonian, CfA, Cambridge, MA, United States.*

Relativistic jets are a common feature of accreting black holes. These streams of outward moving plasma are believed to be accelerated by rapidly rotating magnetic field lines in the central engine. The field lines may be attached either to the accretion disk, in which case the jet is powered by the disk, or directly to the black hole via the ergosphere, in which case the energy for the jet comes from the spin of the black hole. In recent years, numerical MHD simulations of black hole accretion disks have shown that jets form under fairly generic conditions. In at least some cases, the power source for the simulated jets can be traced unambiguously to the spin energy of the black hole. On the observational front, there is evidence in black hole X-ray binaries for a correlation between jet power and black hole spin, suggesting once again a connection between relativistic jets and black hole spin. Both in nature and in simulations, jets form most readily in the presence of geometrically thick disks, possibly because such disks provide more effective collimation compared to thin disks.

205.02 – Disks, Winds, and Jets in AGN: The X-ray View

Christopher S. Reynolds¹

1. *Univ. of Maryland, College Park, MD, United States.*

On both theoretical and observational grounds, it is becoming clear there are crucial interdependences between the accretion disk, winds, and relativistic jets associated with accreting black holes. I shall review progress in understanding these phenomena in active galactic nuclei (AGN) using X-ray spectral and timing observations. In particular, I shall address (1) the implications of recent supermassive black hole spin measurements for our understanding of the radio-loud/radio-quiet dichotomy; (2) the X-ray view of winds in AGN and, especially, the connection between the recently discovered uncollimated mildly-relativistic outflows and other wind/jet components; (3) the recent discovery of relativistic iron line reverberation and the implications for jet physics.

205.03 – Powering Extragalactic Radio Jets in Galaxy Clusters

Brian R. McNamara¹

1. *University of Waterloo, Waterloo, ON, Canada.*

I will review the X-ray methodology for determining the power of radio sources launched into the hot atmospheres of elliptical galaxies and clusters. I will use this method to estimate accretion rates onto massive black holes, and I will discuss powering of jets in galaxies and clusters through the accretion of hot and cold gas and by black hole spin. I will present new results from Russell et al. showing that radio AGN become more efficient radiators as their accretion rates rise, and eventually transform into quasars as they approach the Eddington rate.

205.04 – The Role and Power of Jets Across the Black Hole Mass Scale

Sera Markoff¹

1. *Astronomical Institute Anton Pannekoek, University of Amsterdam, Amsterdam, Netherlands.*

Black hole X-ray binaries (BHBs) are fantastic laboratories for studying accretion processes on timescales millions of times shorter than those in supermassive black holes. During a typical outburst, relativistic jets are launched with both steady flow and discrete ejecta, and then ultimately quenched, over the course of weeks to months. In the process, the system traverses a series of accretion states with enough similarities to AGN classifications to motivate a quantitative comparison. I will discuss the latest results on how BHBs are guiding our ideas about jet launching and internal physics, even for supermassive black holes. Beyond attempts at mapping BHB states to AGN classes, I will also cover some new ideas we are developing about how accretion flows determine jet dynamics as well as particle acceleration.

206 – Black Holes in Globular Clusters

206.01 – Black Holes in Globular Clusters: An Overview

Thomas J. Maccarone¹

1. Physics, Texas Tech University, Lubbock, TX, United States.

I will give an overview of the topic of black holes in globular clusters. These objects are valuable tools for understanding both black hole formation and, potentially, accretion physics: unlike field X-ray binary systems, the black holes in binaries in globular clusters need not have formed through an episode of close binary evolution, meaning that they may have a mass distribution more reflective of that of typical black holes in the Galaxy; they are thus likely to be skewed to higher typical masses, and they may be more likely to end up in close binaries with other black holes or with neutron stars than field systems, making them excellent candidate gravitational wave sources; and finally, they are at known distances. I will discuss the theoretical and observational work that led to a belief that globular clusters did not contain black holes that was fairly widespread until the early 2000's, and set the stage for the remainder of the session in which the observations which have changed that view will be discussed.

206.02 – Modeling Black Holes in Globular Clusters

Natalia Ivanova¹

1. Physics, University of Alberta, Edmonton, AB, Canada.

I will review the current theoretical understanding of what is the population of black holes in globular clusters, as well as challenges in their modeling. Black hole binaries are the tip of the iceberg, and our best link to observations. In a dense stellar environment, such binaries are formed via dynamical encounters. The analyses show that the formation path of black hole X-ray binaries is very different from the well-known formation channels for neutron star X-ray binaries, like binary exchanges and physical collisions. This formation path is composed of several distinct formation stages, where the most crucial one is triple-induced mass transfer.

206.03 – Searching for Black Holes in Milky Way Globular Clusters

Laura Chomiuk^{1, 2}, Jay Strader¹, Thomas J. Maccarone^{3, 4}, James Miler-Jones⁵, Anil Seth⁶

1. Physics and Astronomy, Michigan State University, East Lansing, MI, United States. 2. National Radio Astronomy Observatory, Socorro, NM, United States. 3. University of Southampton, Southampton, Hampshire, United Kingdom. 4. Texas Tech University, Lubbock, TX, United States. 5. International Centre for Radio Astronomy Research, Curtin University, Perth, WA, Australia. 6. University of Utah, Salt Lake City, UT, United States.

The newly upgraded Karl G. Jansky Very Large Array (VLA) has opened a new window onto black holes in globular clusters, thanks to its order-of-magnitude improvement in radio continuum sensitivity. Here, I discuss our search for intermediate-mass black holes and our discovery of two stellar-mass black holes in M22 (the first discovered in a Milky Way globular cluster). I conclude by presenting the newest results from deep VLA imaging of several additional globular clusters.

206.04 – Emission Lines From Tidally Disrupted White Dwarfs and Other Evolved Stars

Drew R. Clausen¹, Steinn Sigurdsson¹, Michael Eracleous¹, Jimmy Irwin²

1. The Pennsylvania State University, University Park, PA, United States. 2. University of Alabama, Tuscaloosa, AL, United States.

When a black hole tidally disrupts a star, accretion of the debris will produce a luminous flare and reveal the presence of a dormant black hole. The accretion flare can also photoionize a portion of the post-disruption debris. We present models of the emission line spectrum produced in the debris released when a white dwarf or a horizontal branch star is tidally disrupted by an intermediate-mass black hole, and discuss the possibility of using the emission lines to identify such events and constrain the properties of the black hole. We also compare the white dwarf disruption models with observations of white dwarf tidal disruption candidates in globular clusters associated with NGC 4472 and NGC 1399. The bright [O III] line observed in each system is consistent with these models, but there are some drawbacks to interpreting these sources as tidally disrupted white dwarfs. On the other hand, the X-ray luminosity and emission line spectrum observed in the NGC 1399 globular cluster are consistent with models of the mild disruption of a horizontal branch star by a 50-200 solar mass black hole.

206.05 – Observations of Black Holes in Extragalactic Globular Clusters

Arunav Kundu^{1, 2}

1. TIFR, Mumbai, Maharashtra, India. 2. Eureka Scientific, Oakland, CA, United States.

The search for black holes (BHs) in globular clusters (GCs) has a long and checkered history. High resolution X-ray observations provide a direct method to detect accreting black holes in GCs. The highly luminous and rapidly variable X-ray source associated with the globular cluster RZ2109 in NGC 4472 was the first such confirmed source. Several other BHs have been detected in GCs in nearby galaxies since then. Follow up optical spectroscopy reveals optical emission lines in some of the sources. These provide interesting insights into the donors, the geometry of the systems, and the masses of the accretors. I will discuss some of the individual BH systems and the picture emerging from the study of the growing population of BHs in GCs.

206.06 – Black Holes in Globular Clusters: A Summary

Steinn Sigurdsson¹

1. Pennsylvania State Univ., University Park, PA, United States.

We summarize the exciting new results on black holes in globular clusters. Discuss the current state of the observational evidence and theoretical prospects for black holes in globular clusters, and, highlight some future prospects and unresolved issues.

300 – AGN II: Winds/jets/accretion (theory) and AGN/Galaxy Connections

300.01 – Observing Relativistic Jet Simulations

Roger D. Blandford^{1, 2}, Jonathan McKinney^{3, 2}, Nadia L. Zakamska^{4, 2}

1. Stanford University, Stanford, CA, United States. 2. KIPAC, Stanford, CA, United States. 3. Univ. Maryland, College Park, MD, United States. 4. Johns Hopkins University, Baltimore, MD, United States.

Despite extensive observations of relativistic jets in blazars and radio galaxies across the entire electro-magnetic spectrum, from radio to gamma-ray wavelengths, many physical properties of jets remain poorly constrained. Much progress has been made in the last decade on understanding the structure of jets and their launching mechanisms using numerical simulations, including treatment of magneto-hydrodynamics in the framework of general relativity. We aim to provide a better connection between the numerical simulations and the multi-wavelength observations by modeling emission of simulated jets. We start with synchrotron emission observable at radio-to-optical frequencies. Relativistic effects dominate the observed properties of jets and are thus included in the radiative transfer. The degree and position angle of polarization, as well as its degree of variability, are emerging as important diagnostics of the geometry of the jet. We also consider non-local effects with the goal of modeling gamma-ray emission extensively observed by the Fermi satellite.

300.02 – The Fermi Bubbles: Possible Nearby Laboratory for AGN Jet Activity

Hsiang-Yi Karen Yang¹, Mateusz Ruszkowski¹, Ellen G. Zweibel², Paul M. Ricker³

1. University of Michigan, Ann Arbor, MI, United States. 2. University of Wisconsin-Madison, Madison, WI, United States. 3. University of Illinois, Urbana, IL, United States.

The two giant gamma-ray bubbles discovered by the Fermi Gamma-ray Space Telescope are nearly symmetric about the Galactic plane, suggesting some episode of energy injection from the Galactic center, such as a nuclear starburst or active galactic nucleus (AGN) jet activity. Using three-dimensional magnetohydrodynamic simulations that self-consistently include the dynamical interaction between cosmic rays (CR) and thermal gas, and anisotropic CR diffusion along magnetic field lines, we show that the key characteristics of the observed bubbles can be successfully reproduced by a recent jet activity from the central AGN. This implies that the Fermi bubbles could be a unique laboratory for studying AGN jet-inflated bubbles. Our simulations allow us to generate maps of the distribution of the magnetic field, radio polarization, and synchrotron, X-ray, and gamma-ray emission. While the source of pressure support of extragalactic AGN bubbles is still poorly known due to observational limitations, we are able to derive constraints on the composition of the Fermi bubbles by comparing our model predictions with the spatially resolved gamma-ray bubble and microwave haze observations.

300.03 – Fermi Bubbles and Periodic Past Activity of the Central Galactic Black Hole

Dmitry Chernyshov¹, Kwong-Sang Cheng², Vladimir Dogiel¹, Chung-Ming Ko³

1. Theoretical Department, Lebedev's Institute of Physics, Moscow, Russian Federation. 2. University of Hong Kong, Hong Kong, Hong Kong. 3. Institute of Astronomy, National Central University, Chung-Li, Taiwan.

We investigate the consequences of the past quasi-periodic activity of the supermassive black hole in the Galactic center due to capture and tidal disruption of stars. This activity will result in plasma outflow towards Galactic halo with velocity of order of 10^8 cm/s. This quasi-periodic injection of hot plasma can produce a series of shocks, where electrons and protons are accelerated to relativistic energies. The shock accelerated electrons can emit gamma-rays by inverse Compton scattering with the relic photons and the Galactic background soft photons whereas the radio to microwave result from synchrotron radiation producing so called Fermi bubbles and WMAP haze. Acceleration of protons on these shocks may be responsible for the formation of cosmic ray spectrum above 10^{15} eV observed near the Earth.

300.04 – The NuSTAR Extragalactic Survey: A First Look at the Distant High-Energy X-ray Background Population

David R. Ballantyne¹, Marco Ajello⁴, David M. Alexander⁵, Roberto J. Assef¹⁰, Mislav Balokovic², Franz E. Bauer⁶, Steven E. Boggs⁷, Kristen Boydston², Carrie Bridge², Finn Christensen⁸, William W. Craig⁷, Agnese Del Moro⁵, Peter R. Eisenhardt¹⁰, Anthony H. Gonzalez¹², Charles J. Hailey⁹, Fiona Harrison², Ting-Ni Lu^{2, 3}, Daniel Stern¹⁰, William Zhang¹¹

1. Georgia Institute of Technology, Atlanta, GA, United States. 2. Caltech, Pasadena, CA, United States. 3. National Tsing Hua University, Taiwan, Taiwan. 4. KIPAC/SLAC, Palo Alto, CA, United States. 5. Durham University, Durham, United Kingdom. 6. Pontificia Universidad Católica de Chile, Santiago, Chile. 7. UC Berkeley, Berkeley, CA, United States. 8. DTU Space, Lyngby, Denmark. 9. Columbia University, New York, NY, United States. 10. JPL/Caltech, Pasadena, CA, United States. 11. NASA/GSFC, Greenbelt, MD, United States. 12. University of Florida, Gainesville, FL, United States.

Contributing teams: NuSTAR Team

One of the primary tasks of the recently launched NuSTAR observatory is to complete an extragalactic survey and provide a sensitive census of the cosmic X-ray background (XRB) source population at >10 keV. Here we report on the first seven identifications of NuSTAR sources serendipitously detected in the NuSTAR extragalactic survey. These NuSTAR-detected sources are approximately ~ 100 times fainter than those previously detected at >10 keV and have a very broad range in redshift and luminosity ($z \sim 0.020-2.923$ and $L_{10-40 \text{ keV}} \sim 4 \times 10^{41}-5 \times 10^{45} \text{ erg s}^{-1}$). We characterise these sources on the basis of X-ray spectroscopy, optical spectroscopy, and broad band optical-mid-infrared spectral energy distribution (SED) analyses. We find a broad range of AGN properties, from low-luminosity AGNs to moderate-high luminosity obscured and unobscured systems. We briefly discuss these results in terms of the overall expected XRB source population.

300.05 – A Chandra Investigation of Empirical Links Between XRB and AGN Accretion

Paul J. Green¹, Markos Trichas¹, Anca Constantin², Thomas L. Aldcroft¹, Dong-Woo Kim¹, Ashley Hyde³, Daryl Haggard⁴, Brandon C. Kelly⁶, Malgosia Sobolewska¹, HongYan Zhou⁵

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California, Santa Barbara, CA, United States.

Striking similarities have been seen between accretion signatures of X-ray Binary (XRB) systems and AGN. XRB spectral states show an inflected correlation between spectral hardness and Eddington ratio while they vary. While we cannot typically track changing AGN spectral states in a human lifespan, we can capture snapshots of a large sample of AGN in different states. We have matched 617 sources from the Chandra Source Catalog to SDSS spectroscopy, and uniformly measured both X-ray and optical spectral characteristics across a broad range of AGN types. We further fit broadband spectral energy distributions with a variety of templates to directly measure bolometric luminosity. We describe the observed correlations, and contrast them with what has been seen for varying XRBs to test a promising probe of accretion disk physics.

300.06 – Catching Actively Growing Galaxies and SMBHs in a High Redshift ($z = 2.23$) Protocluster Environment with Herschel and Chandra

Bret Lehmer^{1, 2}, Adrian B. Lucy³, David M. Alexander⁴, Philip Best⁵, James Geach⁶, Christopher Harrison⁴, Ann E. Hornschemeier^{1, 2}, Yuichi Matsuda⁷, James Mullaney⁴, Ian Smail⁴, David Sobral⁸, Mark Swinbank⁴

1. Johns Hopkins University, Baltimore, MD, United States. 2. NASA GSFC, Greenbelt, MD, United States. 3. University of Oklahoma, Norman, OK, United States. 4. Durham University, Durham, United Kingdom. 5. Institute for Astronomy, Edinburgh, United Kingdom. 6. McGill University, Quebec, QC, Canada. 7. National Astronomical Observatory, Tokyo, Japan. 8. Leiden University, Leiden, Netherlands.

Catching the galaxy and supermassive black hole (SMBH) growth phases of the progenitors to local massive ellipticals is challenging, as they are expected to arise in faint galaxies in the high-redshift protocluster environment. Leading theoretical models characterizing the concurrent formation and growth history of galaxies and their central SMBHs generally require that feedback from AGN plays a crucial role in regulating the growth of galaxy bulges, leading to the local MBH-Mgal relation. AGN feedback processes are most important in the progenitors of the most massive local elliptical galaxies, which likely had their major growth phases in high-density regions at $z > 2-3$. In this talk, I will present our recently published (arXiv:1301.3922) results from a new 100 ks Chandra and Herschel SPIRE survey of a $z = 2.23$ overdensity of quasars and H α emitters (HAEs) in the 2QZ Cluster field – a candidate progenitor structure to local massive galaxy clusters. We have found an excess of luminous AGN in this protocluster and discuss what these observations tell us about how these galaxies eventually evolve onto the local MBH/M* relation.

300.07 – Cosmological Evolution of the FSRQ Gamma-ray Luminosity Function and Spectra and the Contribution to the Background Based on Fermi-LAT Observations

Jack Singal¹, Vahe Petrosian¹, Allan Ko¹

1. KIPAC, Stanford, CA, United States.

The Fermi-LAT has accumulated a large sample of blazars with known flux and spectral index. However, since blazars with harder spectra can be detected to lower fluxes than ones with softer ones with the LAT, the observed bi-variate flux-index distribution is severely truncated at low fluxes and softer spectra. Previously we have used the non-parametric method developed by Efron and Petrosian (EP) to correct the Fermi data for this truncation and obtained the true mono-variate distributions of spectral index and flux (commonly called the logN-logS relation) from which we obtained the blazar contribution to EGB as a function of flux directly from the data (Singal et al. 2012). Extrapolating this to lowest possible fluxes we estimated the total contribution of blazars to the EGB. By now many of the FSRQ blazars are identified with active galactic nuclei and their redshifts measured or obtained from archives (M. Shaw et al., 2012). With the addition of the redshifts we can now calculate the FSRQ blazar luminosities and from the tri-variate luminosity-index-redshift distribution determine the luminosity function and index distribution and their evolutions with redshifts. The EP method can be generalized to this three dimensional case (as we done for SDSS quasars; Singal et al. 2013). In this talk we will present the results from this analysis, which will allow us to compare the density and luminosity evolution of FSRQ blazars with other AGNs. In addition, we can determine the redshift and luminosity (instead of flux) variation of the contribution to the EGB which may allow a more reliable estimate of the total contribution of FSRQ blazars to the EGB.

300.08 – Herschel Observations of Blazars PKS 1510-089 and AO 0235+164

Krzysztof Nalewajko¹, Marek Sikora², Greg M. Madejski³, Katrina Exter⁴, Anna Szostek^{3, 5}, Ryszard Szczerba⁶, Mark R. Kidger⁷, Rosario Lorente⁷

1. University of Colorado, Boulder, CO, United States. 2. Nicolaus Copernicus Astronomical Center, Warsaw, Poland. 3. KIPAC, Menlo Park, CA, United States. 4. KU Leuven, Leuven, Belgium. 5. Jagiellonian University, Krakow, Poland. 6. Nicolaus Copernicus Astronomical Center, Torun, Poland. 7. Herschel Science Center, Madrid, Spain.

We present the results of the Herschel Space Observatory observations of two blazars - PKS 1510-089 and AO 0235+164. Observations were performed in 2011 and 2012, involving two photometric instruments - PACS and SPIRE, covering the wavelength range of 70-500 μ m. Each source was observed quasi-simultaneously with both instruments over 10 epochs. We were able to constrain the spectral peaks of the synchrotron components for both sources. We detected little spectral variability in the far-IR band for either source. For PKS 1510-089, we collected multiwavelength data from Fermi LAT, Swift XRT and UVOT, SMARTS and SMA. Multiwavelength variability characteristics and the results of the SED modeling indicate that two separate emitting regions, located at different distances in the relativistic jet, contribute to the observed emission.

301 – Galaxies & ISM

301.01 – The Structure of the Milky Way's Hot Gas Halo

Matthew J. Miller¹, Joel N. Bregman¹

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We present a structure analysis on the Milky Way's hot gas halo using *XMM-Newton* RGS archival data to measure OVII K α absorption-line strengths towards 26 active galactic nuclei (AGN), LMC X-3, and two Galactic sources (4U 1820-30 and X1735-444). We assume the gas is distributed as a β -model and find best-fit parameters of $n_0 = 4.6^{+7.5}_{-3.5} \times 10^{-1} \text{ cm}^{-3}$, $r_c = 0.35^{+0.29}_{-0.27} \text{ kpc}$, and $\beta = 0.71^{+0.13}_{-0.14}$. These parameters result in halo masses ranging between $M(18 \text{ kpc}) = 7.5^{+22.0}_{-4.6} \times 10^8 M_\odot$ and $M(200 \text{ kpc}) = 3.8^{+6.0}_{-0.5} \times 10^{10} M_\odot$ assuming a gas metallicity of $Z = 0.3 Z_\odot$, which are consistent with current theoretical and observational work. The maximum baryon fraction from our halo model of $f_b = 0.07^{+0.03}_{-0.01}$ is significantly smaller than the cosmological value of $f_b = 0.171$, implying the mass contained in the Galactic halo accounts for 10 - 50% of the missing baryons in the Milky Way. We also discuss our model in the context of several Milky Way observables, including the observed X-ray emission measure in the 0.5 - 2 keV band, the *Fermi* bubbles observed towards the Galactic center, ram pressure stripping in dwarf spheroidal galaxies, and the Milky Way's star formation rate. Although the metallicity of the halo gas is a large uncertainty in our analysis, we do place a lower limit on the halo gas between the Sun and the LMC. We find $Z \gtrsim 0.2 Z_\odot$ based on the pulsar dispersion measure towards the LMC.

301.02 – Spatially-resolved Spectral Analysis of the Hot Gaseous Emission in the M31 Bulge

Mihoko Yukita¹, Jimmy Irwin¹, Ka-Wah Wong¹, Evan Million¹

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We report results from a deep, ~ 400 ks archival Chandra ACIS study of the galactic bulge in M31. We aim to better understand the properties of the hot gas in galactic bulges, which play an important role in galaxy evolution via outflows. Detailed, spatially resolved, spectral analysis of the central 3 arcmin reveal that the hot gas is well characterized by a two-temperature, collisionally ionized, optically-thin plasma model with temperatures $kT \sim 0.2$ and 0.5 keV. The radial temperature profile of the $kT \sim 0.2$ keV component is approximately flat, while the temperature profile of the $kT \sim 0.5$ keV component contains a potential small central peak. The surface brightness of the $kT \sim 0.2$ keV gas follows a beta model distribution that is comparable to the stellar distribution of the bulge. The surface brightness of the hotter $kT \sim 0.5$ keV component follows a significantly different trend. We discuss the interpretation of our results.

301.03 – Unresolved Soft X-Ray Emission from the Galactic Disk

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The soft X-ray sky below 1 keV is spatially smooth after subtracting the local structure. In high galactic latitude regions, emissions from faint unresolved extragalactic point sources, i.e., the Cosmic X-ray Background (CXB), are responsible for $\sim 40\%$ of the soft X-ray emission in the ROSAT R45 band ($\sim 0.44\text{--}1.0$ keV) (McCammon et al. 2002). Since the interstellar X-ray absorption column density is high enough ($\sim 10^{22} \text{ cm}^{-2}$) to block the extragalactic X-ray photons below 1 keV totally in the galactic midplane, it is naturally expected that the X-ray surface brightness in the R45 band decreases by $\sim 40\%$. However, the R45 band surface brightness reduces only by $\sim 20\%$ or less from high galactic latitude regions to the midplane regions. This issue has been known as the “M band problem” (McCammon & Sanders 1990; Cox 2005). M band itself is a name of the energy band which is almost the same as the ROSAT R45 band. Masui et al. (2009) discovered the existence of an unresolved emission in its energy spectrum from a region located in the midplane for the first time and this excess emission is considered to be partly filling the decrease of the extragalactic component in the midplane. Spectral analysis revealed that this excess emission is represented well by a thin thermal emission with a temperature of about 0.8 keV. If this excess emission is an answer for the M band problem, this should be observed in other midplane regions. We searched for this excess emission using archival data of Suzaku which has the lowest and stable background and therefore is optimum for faint soft X-ray emissions. Systematic analysis for over 100 observations with the galactic latitude of $|b| < 5^\circ$ was conducted and finally we detected excess emissions successfully from different 11 regions in the midplane (Mitsuishi et al. in prep). Temperatures range from 0.6 keV to 1.3 keV with different intensities. Our results suggest that these excess emissions are distributed in the whole galactic disk region such as CXB and the Galactic ridge X-ray emission. The origin for these excess emissions is also discussed in this conference.

301.04 – Exploring the Influence of Metallicity on X-ray Binary Formation in Nearby and Distant UV-selected Galaxies

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We present our research on the relationship between the 2-10 keV X-ray luminosity, assumed to originate from X-ray binaries (XRBs), and star formation rate (SFR) in rest-frame UV-selected galaxies across cosmic time – ranging from Lyman break galaxies (LBGs) in the early Universe ($z=1.5\text{--}4$) to Lyman break analogs (LBAs) in the present-day Universe ($z \sim 0.1$). Using the recently acquired 4Ms Chandra Deep Field South (CDF-S) data, we perform X-ray stacking on ~ 4000 $z=1.5\text{--}4$ LBGs and find that the 2-10 keV X-ray luminosity per SFR evolves mildly with redshift, consistent with X-ray binary population synthesis models. Our Chandra observations of 4 GALEX-selected $z \sim 0.1$ LBAs, which are individually X-ray detected, demonstrate elevated X-ray/SFR ratios compared to local galaxies, but similar to $z > 2$ LBGs. This implies that the relatively metal-poor, dust-free, high mode of star formation in LBAs and distant LBGs may yield higher total HMXB luminosity than found in lower SFR galaxies in the local Universe.

301.05 – Explore the Origin of Galactic Coronae with a Chandra Survey of Nearby Highly-Inclined Disc Galaxies

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There are two scenarios for the formation of corona around disc galaxies, either from accretion of the IGM or from galactic feedbacks. We analyze Chandra

data of 53 nearby highly-inclined disc galaxies and study the correlation of their coronal properties with other galaxy properties. We further compare the results to those obtained for elliptical galaxies and from cosmological simulations. We find good correlations of the coronal luminosity L_X with the SFR and the total SN energy input rate from core collapsed (CC) and Ia SNe. The X-ray radiation efficiency has a mean value of $\sim 0.4\%$ and correlates with the dynamical-to-photometric mass ratio M_{TF}/M_* and the CC SN rate surface density, reflecting the opposite effects of mass and feedback concentrations in regulating the coronal X-ray emission. The characteristic temperature shows little dependence on the total/specific SFR, the cold gas content, or L_X . Early-type non-starburst disc galaxies tend to be more Fe-rich, while starburst ones have similar Fe/O ratios of ~ 0.4 solar. The coronal gas radiative cooling rate is typically one order lower than current SFR, suggesting hot mode accretion alone is insufficient to compensate the gas consumed in SF. Recent cosmological simulations involving both accretion and feedback give better matches to observations than predictions from a pure accretion model, but L_X of starburst galaxies are still under-predicted. The combined L_X - M_* relation of both observed and simulated galaxies show a similar shape as the stellar-mass-halo-mass-relation, i.e., with different slopes above and below a transition mass of $M_* \sim 10^{10-11} M_\odot$. The derived L_X - M_{200b} relation shows a nearly linear slope over four orders of magnitude in L_X or M_{200b} . The coronae of disc galaxies tend to be more X-ray luminous, hotter, and lower in Fe/O ratio than those of ellipticals. Our results suggest both accretion and feedback are important in producing coronae around disc galaxies, with feedback probably dominates below the transition mass, while accretion is more important for more massive galaxies. Additional processes, such as mass loading, charge exchange, and various environmental effects, are also needed to explain the observed X-ray properties.

301.06 – X-ray and Ultraviolet Halos Around the Nearby Edge-on Spiral NGC 891

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The origin of the hot and cold halos seen around many spiral galaxies is an important unknown in galaxy evolution because of the two leading, and very different hypotheses. Halos could either be material accreted from the circumgalactic medium or matter ejected from the disk by a 'galactic fountain' of ongoing supernova activity. We examine these formation scenarios with a multiwavelength study of NGC 891, a nearby edge-on Milky Way analog with a giant HI halo and bright X-ray halo that now has very high quality data across the spectrum, including new deep XMM-Newton and Swift UVOT exposures in addition to existing HI, radio continuum, IR, and optical datasets. We argue that the halo does not neatly fit into either picture and may be a composite of accreted and expelled material, and discuss the implications for galaxy halos in general.

301.07 – Charge-Exchange in X-ray Spectrum of M82

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We use a new comprehensive charge-exchange (CX) model to study the diffuse emission in M82 based on one XMM-Newton RGS observation. In addition to the thermal emission from hot outflows, the CX emission may arise from the interaction between the ions in the outflow and the ambient neutral gas. One thermal and one CX component with the same single temperature and the metal abundances can well represent all the emission lines in the RGS spectrum after convolving their relevant Chandra images for broadening line profiles, while the model with a lognormal temperature distribution works even better. We measured the total flux of hot ions to cool gas in M82, and the fraction of CX contribution in each line.

301.08 – The Diffuse X-rays from the Local Galaxy (DXL) Mission

Youaraj Uprety¹, Massimiliano Galeazzi¹, Michael Collier³, Thomas Cravens⁵, Dimitra Koutroumpa³, K. D. Kuntz⁶, Susan T.

Lepri⁴, Dan McCammon², Kelsey Morgan², Frederick S. Porter³, Krishna Prasai¹, Ina Robertson⁵, Steve Snowden³, Nicholas E.

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The Diffuse X-rays from the Local Galaxy (DXL) mission is a sounding rocket mission for the study of Solar Wind Charge eXchange (SWCX) and Local Hot Bubble (LHB) X-ray emission. The mission was successfully launched from White Sands Missile Range, NM on December 12, 2012. It carried two large area proportional counters with thin carbon windows with roughly 1,000 cm² area both in the $\frac{1}{4}$ and $\frac{3}{4}$ keV band. The mission successfully detected the spatial variation of the SWCX due to the He focusing cone. In this paper we will review the mission design and performance and present preliminary results from the December launch.

302 – Gravitational Wave Mission Plans

302.01 – The Proposed Evolved-LISA Mission

Karsten Danzmann¹

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LISA is a laser interferometric gravitational wave observatory in space with 3 spacecraft in heliocentric orbit and million km arm length. It has been studied since 1992 as a joint NASA/ESA mission. An ESA-only version was proposed for the L1 ESA launch opportunity last year, but was not selected. The next call for large ESA missions, L2, is expected for 2013 or 2014, and an evolving LISA concept is being developed by the eLISA Consortium. Contributions from international partners are welcome, presenting a good opportunity for a renewed ESA/NASA partnership on LISA

302.02 – The LISA Pathfinder Mission

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Contributing teams: LISA Pathfinder Team

LISA Pathfinder is a mission of the European Space Mission aimed at demonstrating the space-time metrology required for space-borne gravitational wave observatories like eLISA. In particular the mission aims at experimentally test the detailed physical model of the eLISA instrument using the hardware to be flown on eLISA. This model predicts that no true forces on test-bodies will compete with gravitational signals in excess to $fN/Hz^{-(1/2)}$. The mission is in phase C/D and is due to launch in two years. The talk will describe the mission, its development status, and the metrology under test.

302.03 – Astrophysical Information from Massive Black Hole Coalescences

Scott A. Hughes¹

1. MIT, Cambridge, MA, United States.

The coalescence of massive black holes generates the strongest gravitational waves in the low-frequency band of space-based gravitational-wave antennae. These coalescences are the prime targets of proposed instruments like eLISA. In this talk, I will describe what gravitational-wave measurements of these events will teach us about the populations of black holes which generate them. An instrument like eLISA will make it possible to measure with great precision the masses and spins of coalescing compact binaries even from high redshift ($z \sim 10$) events, probing the early growth of black holes and the galaxies which host them through mergers. Certain configurations of an eLISA-type instrument will also allow us to determine the distance to the source and its position on the sky with moderate accuracy, possibly enabling interesting multimessenger studies of these events.

303 – The Charge Exchange Process in the Solar System and Beyond

303.01 – Solar System X-rays from Charge Exchange Processes

Carey M. Lisse¹, Damian J. Christian², Anil Bhardwaj³, Konrad Dennerl⁴, Scott J. Wolk⁵, Dennis Bodewits⁶, Michael R. Combi⁷, Thomas H. Zurbuchen⁷, Susan T. Lepri⁷

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The discovery of high energy x-ray emission in 1996 from comet C/1996 B2 (Hyakutake) uncovered a new class of x-ray emitting objects. Subsequent detections of the morphology, spectra, and time dependence of the x-rays from more than 20 comets have shown that the very soft ($E < 1$ keV) emission is due to a charge-exchange interaction between highly charged solar wind minor ions and the comet's extended neutral atmosphere. Many solar system objects are now known to shine in the X-ray, including Venus, Mars, the Moon, the Earth, Jupiter, and Saturn, with total power outputs on the MW - GW scale. Like comets, the X-ray emission from the Earth's geo-corona, the Jovian & Saturnian aurorae, and the Martian halo are thought to be driven by charge exchange between highly charged minor (heavy) ions in the solar wind and gaseous neutral species in the bodies' atmosphere. The non-auroral X-ray emissions from Jupiter, Saturn, and Earth, and those from disks of Mars, Venus, and the Moon are produced by scattering of solar X-rays. The first soft X-ray observations of Earth's aurora by Chandra shows that it is highly variable, and the giant planet aurorae are fascinating puzzles that are just beginning to yield their secrets and may be the only x-ray sources not driven directly by the Sun in the whole system as well as properties of hot exo-solar Jupiters. Observations of local solar system charge exchange processes can also help inform us about x-rays produced at more distant hot ionized gas/cold neutral gas interfaces, like the heliopause, stellar astrospheres, galactic star forming regions, and starburst galaxies.

303.02 – Cometary Charge Exchange Emission in Ultraviolet and Soft X-ray Wavelengths

Dennis Bodewits¹

1. University of Maryland, Washington, DC, United States.

Many solar wind charge exchange (SWCX) emission lines fall below the bandwidth covered by current X-ray observatories. The excited states of H- and He-like C, N, and O decay in a radiative cascade which produces photons at X-ray, EUV, and FUV wavelengths. In fact, the most abundant ions in the solar wind, He²⁺ and O⁶⁺, emit at EUV and FUV wavelengths. Model calculations based on O⁹⁺ - H₂ interactions underline the important role of O⁶⁺ ions as line emitters. Helium ion are approximately 200 times more abundant than the oxygen ions that drive cometary X-rays. Low resolution EUVE observations of several comets between 8 - 70 nm allowed for the identification of O III-VI, C V, and He I-II SWCX emission lines. We review the possible diagnostics and the limitations of charge exchange emission in soft X-ray and Ultraviolet wavelengths in this contribution.

303.03 – Charge-Exchange Emission and the Soft X-ray Background

K. D. Kuntz¹

1. Johns Hopkins Univ., Baltimore, MD, United States.

The Soft X-ray Background (SXR) is composed of multiple elements, from the putative Local Hot Bubble (LHB), to the Galactic halo, to the Warm Hot Intergalactic Medium (WHIM). Each of these components fill the FOV of a typical X-ray detector, and must be separated from the other components, foreground emission, and instrumental backgrounds on the basis of spectral, spatial, and temporal variation. Since every neutral atom in the solar system can charge-exchange with highly ionized species in the solar wind, solar wind charge-exchange (SWCX) emission is a ubiquitous foreground. Since the SWCX spectrum is qualitatively identical to that of a very diffuse recombining plasma, which one might expect to see in the LHB or the Galactic halo, it is a significant impediment to study of the SXR. I will describe our current understanding of the three major components of the SWCX emission and the major outstanding issues concerning the SWCX emission. I will discuss the observational techniques for diffuse X-ray emission that avoid problems with the SWCX emission, describe an ambitious program to characterize the SWCX emission, and outline the fundamental limitations of this program.

303.04 – Laboratory Studies of X-ray Spectra Formed by Charge Exchange

Peter Beiersdorfer¹, Rami Ali², Gregory V. Brown¹, Dimitra Kouroumpa³, Richard L. Kelley³, Caroline Kilbourne³, Maurice A. Leutenegger³, Frederick Scott Porter³

1. LLNL, Livermore, CA, United States. 2. University of Jordan, Amman, Jordan. 3. Goddard Space Flight Center, Greenbelt, MD, United States.

Charge exchange between ions and neutral atoms or molecules has been accepted as an important soft producing process in our solar system. By extension, charge exchange may contribute to the X-ray emission of circumstellar material. It may also produce X-ray emission at the boundaries of supernova ejecta and star burst galaxies, or whenever hot plasma collides with neutral matter. X-ray spectra of K-shell and L-shell ions formed by charge exchange have now been studied in a variety of laboratory settings. These experiments have shown several characteristic features of line formation by charge exchange when compared to the X-ray emission produced by electron-impact excitation, e.g., enhancement emission of forbidden lines and of lines from levels with high principal quantum number. They have also shown a dependence on the interaction gas and on the energy of the ion-neutral collision. Moreover, the transfer of multiple electrons is typically preferred, provided the donor molecules or atoms have multiple valence-shell electrons. The laboratory measurements are in qualitative agreement with theory. However, the details of the observed X-ray spectra, especially those recorded with high spectral resolution, can differ substantially from predictions, especially for spectra produced at collision velocities equal to or lower than those found in thermal plasmas or produced with neutral gases other than atomic hydrogen. Puzzling discrepancies can be noted, such as enhanced emission from an upper level with the 'wrong' principal quantum number. Even more puzzling is a recent experiment in which two, co-mixed bare ion species of similar atomic number produce very different Lyman series emission upon charge exchange with a given neutral gas, defying both theoretical predictions and empirical scaling. Laboratory measurements have also shown that some of the characteristic features of charge exchange can be reproduced by radiative electron capture, i.e., by capture of a continuum electron. This process dominates in cold, photo-ionized plasmas, or when hot and cold plasmas mix. Work was performed under the auspices of the DOE by LLNL under contract DE-AC52-07NA27344 and supported in part by an award from NASA's APRA program.

304 – Bridging Laboratory and High Energy Astrophysics

304.01 – Nuclear Data Needs for Astrophysics

Stan E. Woosley¹, Alexander Heger², Robert D. Hoffman³

1. UC, Santa Cruz, Santa Cruz, CA, United States. 2. Monash University, Melbourne, VIC, Australia. 3. LLNL, Livermore, CA, United States.

Nuclear data continues to play a critical role in modern models for stars, supernovae, and nucleosynthesis. Just how critical is sometimes overlooked. I will discuss three representative cases where laboratory measurements are key to answering important current issues. 1) What is the least upper bound to stars that explode as supernovae - 20, 25, 30 solar masses? 2) What stars can explode in the standard core-collapse neutrino transport scenario? and 3) How recent revisions to the standard reaction data base by JINA have altered the yields of massive star nucleosynthesis. If time allows, I will also discuss critical rates that determine the light curves of Type I x-ray bursts on neutron stars.

304.02 – High-Energy-Density Laboratory Astrophysics Experiments on the Omega Laser Facility and the National Ignition Facility

Carolyn C. Kuranz¹

1. University of Michigan, Ann Arbor, MI, United States.

High-energy-density physics facilities, such as the Omega Laser Facility or the National Ignition Facility, can create conditions and processes that occur in astrophysical systems. Sometimes these experimental conditions can be well scaled to a specific astrophysical system. For example, the hydrodynamic instabilities believed to be in the core-collapse supernova SN1987A can be modeled in the laboratory. In these experiments, ~ 5 kJ of laser energy from the Omega Laser facility irradiates a 150 μm plastic layer that is followed by a low-density foam layer. A blast wave structure similar to those in supernovae is created in the plastic layer. The blast wave crosses a three-dimensional interface, which produces unstable growth dominated by the Rayleigh-Taylor (RT) instability. We also investigate the effects of significant radiative fluxes on a shock wave, which is relevant to supernova shocks, supernova remnants and some accretion phenomena. These radiative shocks exhibit large compressions as compared to hydrodynamic shocks, which affect the structure and evolution of the system. A hydrodynamic instability experiment is being performed on NIF with a radiative shock to determine the effects of radiation on the instability growth. The NIF experiment is not scaled to a specific astrophysical case, but could produce similar dynamics as the core-collapse, red supergiant supernova SN1993J where a radiative shock is near a hydrodynamically unstable interface. Experimental and modeling results will be shown and discussed for multiple laboratory astrophysics experiments. This work is funded by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-FG52-09NA29034.

304.03 – Spectral Modeling of Cosmic Atomic Plasmas

Jelle S. Kaastra^{1, 2}

1. SRON, Utrecht, Utrecht, Netherlands. 2. Utrecht University, Utrecht, Utrecht, Netherlands.

Through the advent of high-resolution X-ray spectrometers new X-ray spectroscopic diagnostics have become available. This is due to the deeper observations and the new physical processes that can be studied. Challenges occur because our modeling is not always perfect, and in some cases the clue to advancement is hidden in understanding better the basic atomic processes responsible for the observed spectra. In this contribution I give examples where improvements of the atomic data used in the spectral modeling have been fundamental to exploit these new high-resolution data fully. A long-standing problem is the proper line emissivity and optical depth of Fe XVII ions. This ion is important because it is astrophysically abundant and it is the coolest iron ion with emission lines in the Fe-L band. It is also important because some of its strong lines are sensitive to resonance scattering, and thereby offer a unique opportunity to measure directly optical depths and constrain turbulence. I will discuss some of the long-standing problems associated to this ion as well as the recent developments to improve on the atomic parameters for this ion. There has been an enormous improvement in our knowledge of dielectronic recombination processes over the last years. This has its consequences for the ionisation balance of both collisional plasmas as well as photo-ionised plasmas. I show how this affects the presence and location of stable equilibria in photoionised outflows around (supermassive) black holes. In the same context, new data on inner-shell transitions have allowed to probe this gas in all stages from neutral to almost fully ionised using only X-ray absorption spectra. Examples are the Fe M-shell transitions and the K-shell transitions of oxygen ions. In both cases, improved measurements and calculations of the precise wavelengths have produced accurate outflow velocities of the relevant components. Improved understanding of the fine structure and transitions near the dominant absorption edges of ions also yield new diagnostics for all phases of the intervening ISM, from cold to hot gas dust. The X-ray band offers unique and complementary diagnostic capabilities to the IR dust diagnostics.

305 – Understanding Gamma-Ray Bursts Emission Mechanism in the Fermi Era

305.01 – Spectral and Temporal Properties of Pre-Fermi GRBs

Robert D. Preece¹

1. Univ. of Alabama, Huntsville, AL, United States.

Observations of Gamma Ray Bursts (GRBs) with BATSE and EGRET (on board the Compton Gamma-Ray Observatory) and with Swift satellite have contributed to major advancement in GRB research prior to the launch of the Fermi satellite. In this talk, spectral and temporal properties of the GRBs observed with BATSE and EGRET will be reviewed, highlighting some events with notable features, such as high-energy excess, exceptionally hard spectra, and extended emission. In addition, early afterglow observations made with Swift (BAT and XRT), providing additional insights into the nature of the GRB phenomena, will be briefly discussed.

305.02 – Fermi Observations of GRBs

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Contributing teams: Fermi LAT, GBM Collaborations

During its first years of operations, since August 2008, the GBM has detected ~800 GRBs at keV/MeV energies with about 40 of them being jointly detected by the LAT at MeV/GeV energies. These detections revealed several new and puzzling features, observed mostly at the unexplored-before-Fermi MeV/GeV energy range. I will report these new observational results from Fermi and briefly place them in the context of GRB models.

305.04 – Fermi Observations of the Jet Photosphere in GRBs: Interpretations and Consequences

Felix Ryde^{1, 2}

1. KTH, Stockholm, Sweden. 2. The Oskar Klein Centre for Cosmoparticle Physics, Stockholm, Sweden.

Contributing teams: Fermi LAT, Fermi GBM

Fermi Gamma Ray Space Telescope observations of the prompt emission in gamma-ray bursts (GRBs) has provided evidence that several different spectral features can be present in burst spectra. One such feature is the emission from the jet photosphere, which has been shown to play a significant role in the formation of the spectrum in several strong bursts. In this talk, I will summarise the lessons learned from Fermi observations regarding the behaviour of the photosphere. In particular, I will show that the identification of the photosphere component is important in order to correctly interpret the emission. Finally, I will discuss geometrical and physical processes that will broaden the photosphere spectrum that is expected from a relativistic outflow and show how this can explain the non-thermal spectra seen in many bursts.

400 – SNR/GRB

400.01 – Numerical Simulation-based Jet Model Fits to GRB Light Curves

Binbin Zhang¹, Hendrik Van Eerten², David N. Burrows¹, Andrew MacFadyen²

1. Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA, United States. 2. New York University, New York, NY, United States.

We address the open problem of 'missing' jet breaks in Swift XRT afterglows by fitting afterglows of 34 GRBs with detailed Swift data and late-time Chandra observations to jet models obtained from high resolution hydrodynamics simulations (van Eerten and MacFadyen 2011, 2012). These detailed models allow us to determine GRB jet parameters, including jet break times, jet opening angle, observer angle, shock-accelerated electron distribution and GRB energies, with higher fidelity than allowed by previous afterglow fits based on analytic approximations to the jet evolution. We will present preliminary results from this work.

400.02 – A New Channel for Low-Luminosity GRBs: Tidal Disruptions of White Dwarfs by Intermediate Mass Black Holes

Roman V. Shcherbakov¹, Asaf Pe'er^{2, 3}, Christopher S. Reynolds¹, Roland Haas^{4, 5}, Tanja Bode⁵, Pablo Laguna⁵

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Low-luminosity GRBs or X-ray flashes (XRFs), which often accompany supernovae, are typically ascribed to either the supernova shock breakout or weak GRBs powered by the central engine of stellar mass. We propose the tidal disruption of a white dwarf (WD) by an intermediate-mass black hole (IMBH) as another channel for XRFs. Such disruptions last for 100-5000 seconds. The release of gravitational energy over short time generates a powerful flare. The magnetic field is quickly amplified in the fallback material, and then the BH launches a slow uncollimated jet. The emission from jet photosphere dominates X-rays with Comptonized thermal spectrum, while the expanding jet shell produces most of IR/optical. The prompt flare may be followed by an underluminous fast supernova, resulting from a tidal compression and thermonuclear ignition of a WD. High event rate in dwarf galaxies warrants searches among the known and future transients observed with Swift satellite. We perform detailed dynamical and spectral modeling of a candidate disruption source GRB060218/SN2006aj. The BH mass is independently estimated to be 20,000 solar masses based on (1) the event duration, (2) the jet base radius from the thermal X-ray component, and (3) the properties of a host galaxy. The supernova position is consistent with a center of a dwarf host galaxy. Other potential candidates are the flashes with very weak/absent supernovae such as XRF040701.

400.03 – Searches for Gravitational Waves Associated with Gamma-ray Bursts

Raymond Frey¹

1. University of Oregon, Eugene, OR, United States.

Contributing teams: LIGO Scientific Collaboration, Virgo Collaboration

The progenitors of gamma-ray bursts are expected to include core collapse of massive stars, perturbed neutron stars, or mergers of binary systems consisting of neutron stars or a neutron star and a stellar-mass black hole. Gravitational-wave (GW) emission is expected to accompany such events, each progenitor type giving rise to rather different GW and electromagnetic emission characteristics. We describe strategies developed to search for GW emission from each of these scenarios and the results of such searches with the initial LIGO and Virgo GW detectors. We also discuss the prospects for such searches with the significantly more sensitive advanced GW detectors which will begin coming on line in the next several years.

400.04 – NuSTAR Constraints on the Shock Temperature and Velocity in the Luminous Type II_n Supernova 2010jl

Andreas Zoglauer¹, Eran Ofek², Nicolas Barriere¹, Eric Bellm³, Steven E. Boggs¹, Finn Christensen⁴, William W. Craig⁵, Chris Fryer⁶, Charles J. Hailey⁷, Fiona Harrison³, Stephen P. Reynolds⁸, Daniel Stern⁹, William Zhang¹⁰

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Some supernovae (SNe) show evidence for the existence of large amounts of circum-stellar matter (CSM) ejected months to years prior to the SN explosion itself. Interactions of the SN blast wave with the CSM, in many cases, produce long-lived pan-chromatic signals ranging from the radio to the X-ray regime. Here we report on NuSTAR observations of the extraordinary X-ray bright type-II_n supernova 2010jl taken on Oct 6 2012, roughly 2 years after the explosion. Chandra observations could not constrain the temperature ($8 \text{ keV} < T < 80 \text{ keV}$), but also found a significant drop in the column density between observations taken ~2 months and ~12 months after the explosion. Our observations show clear evidence for interaction between the SN blast wave and a very massive CSM. Thanks to its broad band pass, NuSTAR is able to constrain the shock temperature; in addition, a combined measurement with XMM constrains the column density. This enables us to measure the material between the shock region and the observer, and for the first time to constrain the shock velocity directly using X-ray observations.

400.05 – NuSTAR First Pulsar-wind Nebulae Results

Kristin Madsen¹, Hongjun An⁷, Steven E. Boggs⁶, William W. Craig³, Chris Fryer⁹, Brian Grefenstette¹, Charles J. Hailey⁴, Brian Humensky⁴, Victoria M. Kaspi⁷, Laura A. Lopez¹¹, Hiromasa Miyasaka¹, Kaya Mori⁴, Melania Nynka⁴, Michael Pivovarov³, Stephen P. Reynolds⁸, Takao Kitaguchi¹², Niels J. Westergaard², Daniel R. Wik⁵, Andreas Zoglauer⁶, Finn Christensen², Fiona Harrison¹, Daniel Stern¹⁰, William Zhang⁵

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Montreal, QC, Canada. 8. NCSU, Raleigh, NC, United States. 9. LANL, Los Alamos, NM, United States. 10. JPL, La Canada Flintridge, CA, United States. 11. MIT, Cambridge, MA, United States. 12. Riken, Saitama, Japan.

The Nuclear Spectroscopic Telescope Array (NuSTAR), successfully launched in June 2012, is the first telescope to bring the the hard X-ray (3 to 79 keV) sky into focus. NuSTAR's combination of sensitivity and angular resolution enable it, for the first time, to study the morphology of pulsar wind nebulae (PWNe) in the hard X-ray band above 10 keV. PWNe accelerate particles in the pulsar magnetosphere and/or relativistic wind termination shocks, and as the particles propagate outwards they suffer radiative and adiabatic losses. The morphology of the nebulae as a function of energy constrains the nature of the particle acceleration and propagation. We will present first results of the morphological changes observed with NuSTAR of the two PWNe: G21.5-0.9 and the Crab.

400.06 – SN 1006 from Chandra: Exquisite Testament to Progress in Fifty Years of X-ray Astronomy

P. F. Winkler¹, Satoru Katsuda², Knox S. Long³, Robert Petre⁴, Stephen P. Reynolds⁵, Brian J. Williams⁴

1. Middlebury College, Middlebury, VT, United States. 2. RIKEN, Saitama, Japan. 3. STScI, Baltimore, MD, United States. 4. NASA-GSFC, Greenbelt, MD, United States. 5. NCSU, Raleigh, NC, United States.

Few objects illustrate the progress made in 50 years of X-ray Astronomy as dramatically as the SN 1006 remnant, which was one of the very faintest sources detected by the first generation of X-ray satellites. We will present the most detailed view of SN 1006 yet obtained, a mosaic of 10 overlapping fields, obtained with ACIS on Chandra in a total exposure time of 700 ks. Comparison with Chandra images from earlier epochs allows us to measure the expansion around most of the X-ray shell. The inferred shock velocity is high everywhere, but is significantly higher (5000 km/s) in regions dominated by non-thermal synchrotron emission than in the NW, where the thermal-dominated X-ray shell is expanding at “only” about 3000 km/s. Yet even in the NW there are isolated X-ray knots with non-thermal spectra and high velocities. We will also present a recent deep optical image that reveals extremely faint H α emission around the complete 30-arcmin shell in far greater detail than seen previously. These Balmer filaments delineate the leading edge of the primary shock as it expands outward through a partially neutral medium. Interestingly, we find distinct optical features, both within the interior and at the shell limb, that appear to be bow shocks preceding fast knots of ejecta seen in X-rays. This work is being supported by NASA through grant G02-13066, and by the NSF through grant AST-098566.

400.07 – What Would the Remnant of a Gamma-ray Burst Look Like?

Laura A. Lopez¹

1. MIT, Cambridge, MA, United States.

Although gamma-ray bursts (GRBs) are ubiquitous at cosmological distances, local analogues of these energetic explosions have not been discovered in the Milky Way. However, based on rates of nearby Type Ib/Ic supernovae (SNe), it is reasonable to expect that one of the known Galactic supernova remnants (SNRs) originated from a bipolar or hypernova explosion. In this presentation, I discuss the observables that one would expect from a GRB remnant, including the morphological, spectral, and environmental characteristics that would suggest a bipolar, core-collapse explosion. Furthermore, I will apply these criteria to known Galactic SNRs and demonstrate that one SNR, W49B, is likely to have been a bipolar Type Ib/Ic SN, making it the first of its kind to be discovered in the Milky Way.

400.08 – Determining Progenitors of Young Supernova Remnants from Their Fe K-Shell Emission

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Young Supernova Remnants (SNRs) retain crucial information about their explosion and nucleosynthesis mechanisms. However, interactions with the surrounding circumstellar and interstellar medium can conceal these data and so it is not unusual that even the basic progenitor type (i.e., Ia or core-collapse) of a remnant remains controversial. Here we propose a new method to discriminate the progenitors solely using the Fe K-shell X-ray spectrum. We systematically analyzed Suzaku and Chandra observations of young ejecta-dominated SNRs to determine the intensity and centroid of the Fe-K emission lines. We found that the Fe ejecta in Type Ia SNRs are commonly less ionized than those in core-collapse SNRs. It was found, moreover, that luminosity and centroid of the Fe-K emission are well correlated among each group of Type Ia or core-collapse remnants, and that the more luminous remnants tend to be more highly ionized. These results may reflect the pre-explosion density of the remnants. Evidence of overionization was observed only in core-collapse SNRs, implying their origin to be related to interaction with stellar wind material. Our method can potentially be utilized in systematic studies of extragalactic SNRs with future missions, such as AXSIO, that have high-resolution imaging and spectroscopic capabilities. This will help study, for example, the supernova rate in different ISM environments.

401 – Galaxy Clusters

401.01 – Virial Region of Abell 133 Viewed with the 2.4 Msec Chandra Exposure

Alexey Vikhlinin¹

1. *Harvard-Smithsonian, CfA, Cambridge, MA, United States.*

We present first results from a 2.4 Msec observation of Abell 133 with Chandra (2Msec 'X-ray Visionary Program' plus 400 ksec of HRC GTO time). We detect several tens of isolated X-ray clumps, but the topic of this presentation is the properties of the diffuse intracluster emission. We accurately measure the properties of the intracluster gas, excluding all clumps, all the way out to the virial radius (R200). We observe the emergence of the filamentary structure beyond this radius. We also tentatively locate the global infall shock near the virial radius. We discuss the implications of these results for interpretation of the data from X-ray and SZ cluster surveys, and discuss the prospects for future observations of the cluster outskirts.

401.02 – NuSTAR's Hard Look at the Bullet Cluster: First Results

Daniel R. Wik¹, Allan Hornstrup², Silvano Molendi³, Fiona Harrison⁴, Steven E. Boggs⁵, Finn Christensen², William W. Craig⁶, Desiree Ferreira², Charles J. Hailey⁷, Takao Kitaguchi⁸, Grzegorz M. Madejski⁹, Kristian Pedersen², Daniel Stern¹⁰, Niels J. Westergaard², William Zhang¹, Andreas Zoglauer⁵

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Contributing teams: NuSTAR Team

Mergers between massive galaxy clusters are the most energetic events since the Big Bang, driving shocks and turbulence in the intracluster medium (ICM) that heats the gas and accelerates relativistic particles. Many disturbed clusters host radio halos, and detecting the corresponding inverse Compton (IC) emission is crucial for nailing down the average strength of the ICM magnetic field and thus the total energetics of its relativistic component. However, the lack of X-ray sensitivity at energies above 10 keV have made robust measurements of >10 keV shock temperatures and IC emission extremely challenging. At present, IC detections are of low significance and/or are controversial, primarily due to natural uncertainties in the background of non-imaging instruments. NuSTAR's unprecedented spatial resolution and sensitivity above 10 keV have reduced these uncertainties and have allowed unambiguous confirmation or rejection of previous measurements in the Bullet cluster. This cluster exhibits a luminous radio halo and potentially very hot (>15 keV) gas in a shock. We present preliminary results from two 150 ks observations of the Bullet with NuSTAR, designed to detect a putative IC component and precisely measure the temperature of the shock being driven by the bullet subcluster. Despite detections of IC emission with RXTE and Swift, we find the NuSTAR spectrum to be inconsistent with an IC component at the previously measured flux level. We also present spatially resolved, joint NuSTAR/Chandra spectral fits that constrain the temperatures of the hottest gas in the ICM, with a particular focus on the shock region.

401.03 – The Evolution of Cool Cores in Galaxy Clusters from $z=0$ to $z=1.2$

Michael McDonald¹

1. *MIT, Cambridge, MA, United States.*

We present the latest results from a large X-ray survey of the 80 most massive galaxy clusters discovered with the South Pole Telescope. This unique sample, which has a median redshift of $z \sim 0.7$, allows us to measure the cooling properties of clusters in various stages of evolution and provides new hints into the origin of cool cores, the evolution of cooling flows, and the history of the cooling/feedback balance in galaxy cluster cores. Based on these data, we constrain the epoch of cool core formation to be $z \sim 1$, and show compelling evidence that the cool cores we observe in the local Universe are a direct result of the cooling flow problem - gas which is unable to cool piles up in the cluster center, leading to an overdensity of low-entropy gas.

401.04 – How AGN Feedback Evolves in Clusters of Galaxies

Julie Hlavacek-Larrondo¹

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We present work on the most extreme brightest cluster galaxies (BCGs), those that lie in massive and strong cool core clusters. Our sample covers the redshift range $z=0.0-0.6$ and reveals strong evolution in how radiative AGN feedback operates, such that the black holes in these systems have become 10 times fainter in the X-rays over the last 5 Gyrs. The fraction of BCGs with radiatively efficient nuclei doubles in the last 5 Gyrs, implying that a significant fraction of $z=1$ BCGs will host quasars at their centres, therefore complicating the search for such clusters at high redshift. We furthermore show that mechanical AGN feedback has not significantly evolved over the last 5 Gyrs, implying that extreme 'radio mode' feedback in clusters starts to operate as early as 7 - 8 Gyrs after the Big Bang.

401.05 – Feedback at the Working Surface: A Joint X-ray and Low-Frequency Radio Spectral Study of the Cocoon Shock in Cygnus A

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We report on preliminary results from a joint spectral analysis of the cocoon shock region in Cygnus A using deep archival Chandra data and new low-frequency radio data from LOFAR. Being both bright in X-rays and the most powerful radio source in the local universe, the FR II radio galaxy Cygnus A represents an ideal opportunity to study the interaction between the jets produced by the central AGN and the surrounding intracluster medium (ICM) in which that AGN is embedded. Using the entire 235 ksec archival Chandra exposure, we have performed a spatially resolved, X-ray spectral analysis of the ICM in Cygnus A. By combining the resulting X-ray images and temperature maps with spectral index maps between 30-80 MHz and 120-180 MHz calculated from a recent, deep

LOFAR observation, we can resolve the X-ray and radio emitting plasmas in any given region on spatial scales of 3-4 kpc over the central 100 kpc. We clearly resolve the cocoon shock surrounding Cygnus A and determine the Mach number of the shock as a function of position angle. Temperature jumps associated with this shock are detected over a large fraction of the total shock circumference. Significant non-thermal emission is also detected in the regions surrounding the SE and NW leading edges of the shock near the hotspots. In this talk, we will present a detailed analysis of the energetics of this interface region between the radio plasma inside the cocoon shock and the X-ray emitting gas outside the shock. Inside the shock, we will present constraints on the emission mechanisms in the jet, counter-jet, and hotspots based on the combined radio and X-ray spectra. Using maps of the spectral age derived from the LOFAR data and independent age estimates based on various cavity features seen in the X-ray image, we will present a picture of the evolution of the shock region in Cygnus A over the past 50 Myr. Finally, we will discuss the implications these observations have for AGN feedback models as well as the energy transfer mechanism itself.

401.06 – ICM Properties and Gas Mixing in the Stripped Tails of Two Nearby Early-type Cluster Galaxies

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We present results from new, deep observations of the Virgo cluster early-type galaxy NGC 4552 (M89) and archival observations of the Fomax cluster early-type galaxy NGC 1404. Both galaxies are falling into their host clusters and show ram-pressure stripped gas tails due to their motion through the cluster ICM. The temperature profiles along the gas tails trace the mixing between the cooler galaxy gas and the hotter cluster gas. We measure these temperature profiles along the tails for both galaxies and compare them with specifically tailored viscous hydrodynamic simulations. These simulations show that if the viscosity is suppressed many orders of magnitude relative to the Spitzer value, the galaxy and cluster gases are rapidly mixed and the temperature of the tail rapidly equilibrates to that of the ambient ICM. In contrast, we find that the temperature of the gas in both tails remains well below that of the ICM for a distance at least several times the radius of the remnant merger core, suggesting that the viscosity of the ICM is at least a few percent of the Spitzer value.

401.07 – Intragroup and Galaxy-Linked Diffuse X-ray Emission in Compact Groups of Galaxies

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Isolated compact groups of galaxies present a range of dynamical states, group velocity dispersions, and galaxy morphologies with which to study galaxy evolution, particularly the properties of gas both within the galaxies and in the intragroup medium. As part of a large, multi-wavelength examination of compact groups, we present an archival study of diffuse X-ray emission in a sample of compact groups of galaxies observed with the Chandra X-ray Observatory. We find that several of the groups in our sample exhibit detectable diffuse emission. However, unlike large-scale emission in galaxy clusters, the diffuse features in the majority of the detected groups are linked to the individual galaxies, in the form of both plumes and halos likely as a result of star formation or AGN activity, as well as in emission from tidal features. Several groups appear to be consistent with the cluster scaling relations between X-ray luminosity, plasma temperature, and velocity dispersion due to vigorous star formation within the galaxies, however the majority of groups fall systematically below these relationships. We find that X-ray luminosity increases with decreasing group HI to dynamical-mass ratio with tentative evidence for a dependence in X-ray luminosity on HI morphology whereby systems with intragroup HI indicative of strong interactions are considerably more X-ray luminous than passively evolving groups. Finally, our findings suggest that the hot gas in these groups is not in hydrostatic equilibrium and these systems are not low-mass analogs of rich groups or clusters.

401.08 – Probing Non-thermal Emission from Clusters with Gamma-Ray and Radio Observations

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In addition to the thermal gas, galaxy clusters are expected to host significant populations of energetic cosmic rays, with strong observational evidence for this population coming from the detection of diffuse synchrotron radio emission from many clusters. Relativistic particles may be accelerated throughout the cluster by a number of processes including 1) by accretion and merger shocks during structure formation, 2) particle dark matter annihilation or decay, and 3) supernovae associated to star formation in cluster galaxies. All of these processes would lead to some level of associated gamma-ray emission. While diffuse gamma-ray emission has not yet been detected from clusters, we can use the combination of radio and gamma-ray observations to constrain each of these processes. In particular, we will present constraints on the origin of radio halos in clusters, the dark matter annihilation cross-section, and predictions for the minimum expected gamma-ray emission from clusters.

402 – Stellar Compact III: X-ray Binaries, Transients and ULX Sources

402.01 – NuSTAR's First Results for Cyclotron Lines Sources

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Contributing teams: NuSTAR Team

By studying phase resolved spectra of accreting neutron star X-ray binaries we can gain insight in their magnetic field geometry and the physical conditions inside the accretion column. The recently launched Nuclear Spectroscopic Telescope Array (NuSTAR) offers unprecedented sensitivity and spectral resolution in the hard X-rays up to 79keV and is therefore ideally suited to perform high-quality spectroscopy on short time scales of neutron star binaries. We will present first results for Her X-1 and Vela X-1, two famous sources with prominent Cyclotron Resonant Scattering Features (CRSF). CRSFs provide the only direct way to measure the surface magnetic field of neutron stars. In Vela X-1, the most prominent CRSF is the first harmonic around 55keV, seen with variable depth at all phases. The fundamental CRSF around 25keV is only measured during a very narrow pulse phase interval, greatly constraining the emission geometry. In Her X-1, the energy of the fundamental line around 37keV changes by up to 10keV with pulse phase. We also investigate changes with the super-orbital 35d phase, but find no correlation to the CRSF energy. Besides the CRSFs, the underlying powerlaw slope is also varying in both sources, showing that different parts of the accretion column have clearly different physical conditions. With the spectral resolution of NuSTAR, it is now possible to study the shape of the CRSF in detail and we will compare it to theoretically predicted line shapes.

402.02 – Long-term Monitoring of Supergiant Fast X-ray Transients with Swift: From Hours to Years

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Supergiant Fast X-ray Transients (SFXTs) are HMXBs with OB supergiant companions and are known for hour-long X-ray outbursts characterized by 3-5 orders of magnitude luminosity increases. Our Swift Supergiant Fast X-ray Transients Project has investigated in the last few years both these bright flares and the emission outside the bright outbursts, where the high sensitivity of the X-Ray Telescope (XRT) can be best exploited. In particular, by taking advantage of Swift's flexible scheduling, we have been performing regular monitoring with the XRT of several SFXTs and candidates, with 2-3 observations per week (1-2 ks) for at least one year per source. This has allowed us to determine their long-term properties, and to obtain an assessment of the fraction of the time these sources spend in each luminosity phase (outbursts, intermediate level, and quiescence) and their duty cycle of inactivity by means of very sensitive and non-serendipitous observations. We present the most recent results from the 2011-2013 monitoring campaigns.

402.03 – Interactions of X-ray Binaries with Their Surrounding Material

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We can observe the interactions of high mass X-ray binaries with their surrounding material in two complementary ways: variability over long time scales, and direct infrared observation of dust/gas. This gives unprecedented clues on the formation and evolution of those systems. Using Herschel infrared observations of high mass X-ray binaries and of ultra-luminous X-ray sources, we aim to detect and characterize the surrounding material. In the case of ultra-luminous X-ray sources, due to the enormous amount of energy radiated, strong interactions with their environment are expected, particularly if the emission is not beamed and if they host an intermediate mass black hole. This provides a unique test for the existence of such objects. The Digital Access to a Sky Century at Harvard (DASCH) is a project to digitize and analyze the scientific data contained in the 530 000 Harvard College Observatory plates taken between the 1880s and 1990s, which is a unique resource for studying temporal variations in the universe on 10-100 yr timescales. The Be star SAO 49275 shows significant slow variability of 1 magnitude on time scales 10-50 years. This variability seems connected to the formation and disappearance of the accretion disk of the Be star, maybe triggered by the presence of a compact object companion, possibly a white dwarf.

402.04 – The First Dynamical Mass Measurement for an Ultraluminous X-ray Source

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Ultraluminous X-ray sources may be the long sought intermediate mass black holes, or massive stellar mass black holes with special radiation mechanisms. We have been pursuing the dynamical mass measurements for some of the nearby ultraluminous X-ray sources with their optical counterparts identified. Here we report our Gemini and Keck observations of an ultraluminous X-ray source in M101, for which we find a 8-day period from the line shifts of its Wolf-Rayet star secondary, and obtain a solid lower limit of 5 solar masses for the black hole. Further considerations of the Eddington limit for thermal states and the accretion disk formation in a wind-fed system both suggest the black hole can be more massive than 60-80 solar masses.

402.05 – Discovery of Quasi-periodic X-ray Dips from the ULX NGC 5408 X-1: Implications for the Accretion Geometry

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The nature of ultraluminous X-ray sources (ULXs) remains mysterious. It is not clear whether they are simply scaled-up accreting binaries, i.e., intermediate-mass black holes (mass range of a few 100-1000 solar masses) in binary orbits around companion stars accreting at a sub-Eddington rate or if they are stellar-mass black holes accreting and emitting via a super-Eddington mechanism. Perhaps the ULX population comprises both categories. We present evidence from an archetypal ULX, NGC 5408 X-1 (X-ray luminosity $> 10^{40}$ ergs/sec), that the source accretes in a geometry similar to that of Roche lobe overflow binaries. Using the approximately 3.5 years of Swift/X-ray monitoring data of the source we detect two distinct phenomena: (1) a quasi-sinusoidal, energy-dependent (modulation amplitude decreases with increasing energy upto 8 keV) modulation of the X-ray flux with a period of 112 days and (2) quasi-periodic, energy-independent dips in the X-ray intensity that recur on average every 243 days and with a variance of 23 days, suggesting a moderately high inclination. These two modulations (including their phase separation) appear to be consistent with the predicted variations for Roche-lobe accreting binaries with low-mass ratios, $q = M(\text{donor})/M(\text{accretor})$. The smooth component can be produced by absorption/obscuration by two spatially distinct bulges along the outer rim of the accretion disk (produced by the tidal effects of the massive companion star) while the sharp dips are possibly produced by absorption due to clumps of material produced by the accretion stream - disk impact. We present an idealized accretion geometry of ULX NGC 5408 X-1 that is consistent with these modulations.

402.06 – A State Transition of the Luminous X-ray Binary in the Low-Metallicity Blue Compact Dwarf Galaxy I Zw 18

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We present a measurement of the X-ray spectrum of the luminous X-ray binary in I Zw 18, the blue compact dwarf galaxy with the lowest known metallicity.

We find the highest flux yet observed, corresponding to an intrinsic luminosity near 1×10^{40} erg/s establishing it as an ultraluminous X-ray source (ULX). The spectrum shows distinct curvature indicative of a black hole X-ray binary in the thermal state. A previous measurement of the X-ray spectrum obtained at lower flux shows a harder spectrum that is well described by a powerlaw. Thus, the binary appears to have state transitions similar to those observed from stellar-mass black hole binaries. Spectral fitting suggests that the black hole mass is in the range 20-60 M_{\odot} if the black hole is stationary and above 60 M_{\odot} if maximally-rotating. If the observed state transition occurs at a luminosity similar to that found for stellar-mass black hole binaries, then the black hole mass must be at least 85 M_{\odot} , near the maximum mass predicted for black holes formed via stellar collapse in a low metallicity $Z/Z_{\odot} = 0.019$ environment.

402.07 – First Models of Neutron Star X-ray Bursts with too Short Recurrence Times

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Type I X-ray bursts are frequently observed thermonuclear flashes from accreting neutron stars. Theory explains them as the burning of accreted hydrogen and helium on the neutron star surface, after which it takes at least hours for enough new fuel to accumulate. In rare cases, however, the next burst is observed after a recurrence time of mere minutes. This has been a mystery since the 1980s. We present the first detailed numerical models that explain how fuel may be left over after a burst, and how this can reignite to produce the next burst on roughly the observed timescale of minutes. We compare the simulated distribution of short and long recurrence times to a large observational study that we previously performed, and we discuss the implications of our models for turbulent mixing in the neutron star envelope.

402.08 – Determining Neutron Star Masses and Radii using Energy-resolved Waveforms of X-ray Burst Oscillations

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Precise, simultaneous measurements of the mass M and radius R of neutron stars can yield uniquely valuable information about the still uncertain properties of cold matter at several times the density of nuclear matter. We have used a Bayesian approach to explore how well M and R could be measured using data on X-ray burst oscillations obtained with a future space mission having 2-30 keV energy coverage and an effective area of 10 square meters, such as the proposed LOFT or AXSTAR missions. We have done this by generating synthetic observed waveforms for a variety of neutron star and hot spot properties and then determining the joint likelihood distributions of the parameters in a standard fitted model, given each synthetic waveform. We assume that 1 million counts have been collected from the hot spot and that the total background contributes about the same number of counts. We find that if the hot spot is within 10 degrees of the rotation equator, both M and R can usually be determined with an uncertainty of about 10%. If instead the spot is within 20 degrees of the rotation pole, the uncertainties are so large that waveform measurements alone provide no useful constraints on M and R . Observation of an identifiable atomic line in the hot-spot emission always tightly constrains M/R ; it can also tightly constrain M and R individually if the spot is within about 30 degrees of the rotation equator. These precisions can usually be achieved even if the burst oscillations vary with time and data from multiple bursts must be used to obtain 1 million counts from the hot spot. Independent knowledge of the observer's inclination can greatly reduce the uncertainties, as can independent information about the background. Knowledge of the star's distance can also help, but not as much. Deviations of the actual shape of the hot spot, the actual spectrum of the emission, and the actual beaming function from those assumed in the fitted model increase the uncertainties, sometimes by a large factor, and can bias M and R estimates. These results are based on research supported by NSF grant AST0709015 and funds of the Fortner Endowed Chair at the University of Illinois, and by NSF grant AST0708424 at the University of Maryland.

402.09 – Gamma-ray Observations of the Microquasars Cygnus X-1, Cygnus X-3, GRS 1915+105, and GX 339-4 with Fermi-LAT

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Detecting gamma-rays from microquasars is a challenging but important endeavor for understanding particle acceleration, the jet mechanism, and for testing leptonic/hadronic emission models. In this talk, we present results from a 1-d and 10-d likelihood analysis of ~4 years worth of gamma-ray observations (0.1-10 GeV) by Fermi-LAT of Cyg X-1, Cyg X-3, GRS 1915+105, and GX 339-4. This allowed us to sample a variety of states and transitions in these X-ray bright microquasars. Our analysis reproduced all but one of the previous gamma-ray outbursts of Cyg X-3 as reported with Fermi or AGILE. In addition, there are 5 days on which Cyg X-3 is detected at a significance of ~5 σ that are not reported in the literature. We also find evidence for persistent gamma-ray emission from

Cyg X-3 which appears to be unrelated to the jets. There are several days on which Cyg X-1 displays low-significance ($\sim 3-4\sigma$) excesses, two of which are contemporaneous with reported gamma-ray flares detected (also at low significance) by AGILE. For GRS 1915+105 and GX 339-4, we derive 3σ upper limits of 3.9×10^{-6} ph/cm²/s and 4.0×10^{-6} ph/cm²/s, respectively, on the flux in the 0.1–10 GeV range. These results enable us to propose a list of general conditions which appear to be necessary for the detection of gamma-rays from microquasars.

403 – AGN III: Transients and Low Luminosity/Mass AGN

403.01 – The Swift Monitoring Campaign of Sagittarius A*

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Starting in 2006, the center of our Galaxy has been monitored on a nearly daily basis with the X-ray telescope on-board the Swift satellite. The short pointed observations have offered a unique view of the long-term X-ray behavior of Sgr A*, in particular of its X-ray flaring properties. The Swift campaign also provides an excellent setup to closely monitor the interaction of the supermassive black hole with the dense cold gas cloud (G2) that is on a collision course with Sgr A* and is projected to make a close encounter in the fall of 2013. I will present the results of 7 years of Swift X-ray monitoring of Sgr A*, and give an outlook of how this program can be used to study the X-ray emission as G2 breaks up and feeds gas to the supermassive black hole.

403.02 – NuSTAR Detection of High-energy Emission and Fast Variability from a Sagittarius A* X-ray Flare

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Contributing teams: NuSTAR Team

Sagittarius A* (Sgr A*) is a supermassive ($\sim 4 \times 10^6 M_{\odot}$) black hole that lies at the dynamic center of our Galaxy. Although Sgr A* spends most of its time in a low luminosity emission state (bolometric luminosity $\sim 300 L_{\odot}$), it exhibits frequent flares in the near infrared and in the X-ray band. The radiation processes giving rise to these flares have yet to be identified. Here we report the detection of several X-ray flares with the recently launched NuSTAR mission. The brighter flares have a spectrum extending to at least 40 keV, and one flare exhibits variability on a 100s timescale. These spectra favor the synchrotron (with a cooling break) emission mechanism, implying that hard X-ray light curves trace the acceleration of energetic particles.

403.03 – A 200-Second Quasi-Periodicity After the Tidal Disruption of a Star by a Dormant Black Hole

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Supermassive black holes are known to exist at the center of most galaxies with sufficient stellar mass. In the local universe, it is possible to infer their properties from the surrounding stars or gas. However, at high redshifts we require active, continuous accretion to infer the presence of the SMBHs, which often comes in the form of long-term accretion in active galactic nuclei. Supermassive black holes can also capture and tidally disrupt stars orbiting nearby, resulting in bright flares from otherwise quiescent black holes. Here, we report on a 200-second x-ray quasi-periodicity around a previously dormant SMBH located in the center of a galaxy at redshift $z = 0.3534$. This result may open the possibility of probing general relativity beyond our local universe.

403.04 – Late-time Observations of the New Class of Relativistic Tidal Disruption Flares

Stephen B. Cenko¹

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The high-energy transient Sw J1644+57, discovered by the Swift satellite in 2011, has been suggested to result from the tidal disruption of a star by a supermassive black hole. Aside from the thermal emission associated with the accretion disk formed by the returning stellar debris, the outburst unambiguously triggered the formation of a relativistic jet, leading to luminous X-ray emission and a long-lived radio transient. Shortly thereafter, another high-energy transient source, Sw J2058+05, was also suggested as a possible member of this new class of relativistic outbursts. Here we present late-time multi-wavelength observations of both of these sources, as part of a program to track their long-term behavior and better understand the ultimate processes responsible for these remarkable transients.

403.05 – PS1-10jh: The Partial Disruption of a Main-Sequence Star of Near-Solar Composition

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When a star comes within a critical distance to a supermassive black hole, immense tidal forces can remove a significant fraction of the star's mass, resulting in a stream of debris that falls back onto the black hole and powers a luminous flare. I will be describing the results of hydrodynamical simulations to demonstrate that self-gravity, while unimportant along the direction parallel to the debris, provides significantly confinement across the debris. As a consequence, the stream has a negligible surface area and makes almost no contribution to either the continuum or line emission. We additionally find that the debris stream is strongly compressed and virialized when it returns to pericenter, resulting in a teardrop-shaped structure with a temperature profile similar to that of a Shakura-Sunyaev accretion disk, which grows at a speed somewhat less than the star's original speed at pericenter. We propose that any observed emission lines are not the result of collisional excitation, but are produced similarly to the broad-line regions commonly observed in active galactic nuclei. As each line within a broad-line region is kinematically linked to a particular location in the accretion disk, we suggest that the absence of a line indicates that the accretion disk does not yet extend to the distance required to produce that line. This model can be used to understand the spectral properties of the tidal disruption event PS1-10jh, for which HeII lines are observed, but H γ is not. We show that a partial disruption of a main-sequence star of near-solar composition can reproduce this event.

403.06 – The Sharpest Spatial View of a Black Hole Accretion Flow from the Chandra X-ray Visionary Project

Observation of the NGC 3115 Bondi Region

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Spatially resolved X-ray spectra of hot gas within a black hole accretion flow provide powerful constraints on accretion models. However, very few nearby supermassive black holes have large enough Bondi radii to be spatially resolved even with Chandra. The best candidate for such a study is the 4-5 arcsec (188-235 pc) Bondi region of the nearest billion solar mass supermassive black hole in the S0 galaxy NGC 3115. We present observational results from our Chandra X-ray Visionary Project (XVP) of NGC 3115, a deep 1 Msec observation that allows us to remove most contaminating X-ray point sources in the region close to the black hole, and to create the first detailed density and temperature profiles of the gas within the Bondi region of a radiatively inefficient accretion flow. Interpretation of the results are also discussed.

403.07 – Modeling the Accretion Flow Onset in the Low-Luminosity Active Galactic Nucleus of NGC3115

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The superb angular resolution of the Chandra satellite allows us to probe accretion flows in AGNs on scales comparable to the radius of the black hole (BH) gravitational influence (the 'Bondi radius'). X-ray emission from the onset region of the accretion flow has recently been seen in a 1Ms X-ray visionary project (XVP) observation of NGC3115. I discuss the theoretical modeling of those data with the inflow-outflow solution of gas dynamics. The BH is fed by stellar winds, most of which outflow from the region, while a small fraction settles into a radiatively inefficient accretion flow (RIAF). The galactic potential, line cooling, and small-scale feedback via conduction all influence the behavior of the gas. The X-ray emission of modeled tenuous gas is computed based on ATOMDB 2.0. The set of radius-dependent hot plasma X-ray spectra is combined with contributions from unresolved point sources to fit the observations. A good joint fit to the observed radius-dependent spectra is readily found for a realistic model which includes all relevant physics. All projection effects are self-consistently taken into account in the radiation modeling. The observations combined with theoretical modeling illuminate the intricate process of AGN feeding at low luminosity, help to constraint the accretion rate and the BH mass, and provide useful insights into feeding of more powerful AGNs. The accretion rate in models with small-scale feedback is found to be much lower compared to the accretion rate in a simplistic Bondi model. Our model was previously successfully applied to Sgr A* and will be applied to a variety of other sources in the near future.

403.08 – Probing the Origin of the Intermediate Mass Black Hole ESO 243-49 HLX-1

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While it is widely accepted that most (perhaps all) galaxies host a supermassive black hole in their centers, how these black holes form is not understood. Two leading theories propose that they are formed either from hierarchical mergers of stellar mass black holes, or from the growth (through accretion and/or mergers) of primordial black holes formed through the direct collapse of $\sim 10^{4-6} M_{\odot}$ gas clouds shortly after the Big Bang. Both theories predict the existence of intermediate mass black holes with masses in the range of $\sim 10^{2-5} M_{\odot}$. Intermediate mass black holes are also important as they may have contributed significantly to the epoch of reionization, could constitute catalysts of dark matter annihilation in galaxy halos, and are predicted to be strong sources of gravitational wave radiation. However, observational evidence for the existence of black holes in this mass range has until recently been lacking. Arguably, the best candidate intermediate mass black hole is currently the hyperluminous X-ray source HLX-1 in the S0a galaxy ESO 243-49, with a maximum X-ray luminosity of $1.3 \times 10^{42} \text{ erg s}^{-1}$, $\sim 1,000$ times above the Eddington limit for a $10 M_{\odot}$ black hole. The current mass estimates (derived from Eddington scaling, modeling the thermal emission from the accretion disc, and from limits obtained from the detection of ballistic jets) put the black hole between 9×10^3 to $9 \times 10^4 M_{\odot}$. Here I will present the latest results of broadband spectral energy distribution modeling making use of observations of HLX-1 with the HST, VLT, XMM-Newton, and Swift telescopes. With these data we attempt to ascertain the nature of the environment around HLX-1 and thus determine the origin of this unique object.

